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ABSTRACT

The overall theme of the 7th International Organization for Science and Technology Education (IOSTE) symposium was "science and technology education in a demanding society". The aim of the symposium was to examine the state of science and technology education in the context of the main theme and to reflect on desirable and feasible educational innovations by exchanging and discussing ideas and practical experiences. The main body of the symposium was organized along two subthemes: claims and strategies, and strategies and empirical evidence. This book includes the following keynote addresses: (1) "Education: The Key Factor for the Positive or Negative Image of Science and Technology in Society" (Jan Terlouw); (2) "A Case from a World in Turmoil" (Prins Nevhutalu); (3) "Education in a Changing World, "Seen through the Eyes of a Policy-maker" (Mark Frequin); and (4) "Innovations in Science Education and Evidence from Classroom Learning" (Piet Lijnse). The following reviews are included under the subtheme "Claims and Strategies": (1) "STS Education: Contents and Teaching Methods, Assessment, and Teacher Education" (Arthur Jennings); (2) "STS Cross Curricular Themes: Environmental Education and National/Local Development" (David Cox); (3) "Science/Technology Education: Contents and Teaching Methods" (John Gilbert); (4) "Science/Technology Education: Teacher Education (Shosana Keiny). Reviews under the subtheme "Strategies and Empirical Evidence" include: (1) "STS Education: Content and Teaching Methods" (Uri Zoller); (2) "STS Cross Curricular Themes: Environmental Education and Decision Making" (Martha Monroe); (3) "Science/Technology Education: Contents and Teaching Methods" (R. Fleming); and (4) "Science/Technology Education: Education and Industry" (Graham Mulroney). (JRH)

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Trends in Science and Technology Education

Reviews and Keynotes of the 7th IOSTE-symposium

• part 4

Jacques van Trommel (ed.)

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7th IOSTE Symposium Science and Technology Education in a Demanding Society
23-31 August 1994 De Koningshof Veldhoven, The Netherlands

7th IOSTE Symposium

Science and Technology Education
in a Demanding Society

23 - 31 August 1994

Trends in science and technology education

A review of the 7th IOSTE-symposium,
organized in August 1994 in the Netherlands

Part 4

De Koningshof Veldhoven, The Netherlands

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Foreword

This volume completes the proceedings of the 7th IOSTE-symposium; organized in August 1994 in the Netherlands.
Over 200 hundred people participated, including spouse, for whom a separate touristic programme had been organized.
Three volumes with the submitted papers for discussion sessions and workshops were available at the opening of the symposium. We, the symposium organizers thought it of value also to visualize some of the symposium itself, the process. To that purpose it was decided to put the keynote speeches and a number of reviews, covering all papers and sessions, in a separate and concluding volume. The reviews and keynotes, togehter with the paper volumes, hopefully give the reader a good overview of the recent "world trends in science and technology education", as has been presented and discussed at the 7th IOSTE-symposium and making this meeting more that an instantanious picture for whom present. It also enables the symposium participants to learn about what has been presented and discussed in sessions they could not attend.
Needless to say that we are most thankful for the work the reviewers did.

From the many reactions during and after the symposium I received, as chairman, one may conclude that this meeting was successful in meeting the participants' expectations. A great number of people worked hard to prepair for the symposium and therefore the compliments I received are in the first place for them:

- the large group of paper reviewers, chaired by Kerst Boersma and Koos Kortland, contributed with their meticulous work a lot to the quality on the academic side. Boersma and Kortland, my co-editors of the three papervolumes, I also thank for their help and advices in preparing for this volume.
- Lammie Stoffers, chief secretary within SLO, together with her staff, did a tremendous job in producing all the symposium publications.
- Francien Morshuis, Ingrid Schoenmakers and Xandra de Zeeuw took care of the administrative side. A special word of thanks for Xandra de Zeeuw who, short before the symposium, had to do the whole administration job all alone and she managed.
- Perfect partner and social programmes were prepared and carried out by three students of a college for tourism and leisure management. Saskia borgers, Carin Oosterbeek and Patricia van Woersem I don't need to thank for the job; the participants in their programme did!
- Joost Borsboom and Ger van der Kroft saw after the internal communication with the "symposium daily"
- Ton Plug, with whom I worked closely together for over one year, on the overall organization.

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A number of sponsors enabled us to reduce the symposium fee and made it possible to invite many colleagues from less rich countries to participate into the 7th IOSTE symposium.
We are most thankful for their generosity

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Jacques van Trommel,
symposium chairman.

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Introduction

Jacques van Trommel, editor

The 7th IOSTE international meeting had as overall theme "Science and Technology Education in a demanding Society". The choice for this title had as a rationale:

Society more and more expects education to contribute to preparation for life, including dealing with social issues.
Education is to prepare students not only for further education and employment but also to contribute to the creation of a citizenry able to understand personal and social issues, able to make educated and thoughtful decisions on these issues and act accordingly.

Taking this in consideration as the context for the symposium it was concluded that we, as science educators, should reflect on these demands and expectations. To what demands should education respond, to what extend and in what way?
What research, developments and innovations are required in this respect?

To set the scene for the symposium some keynote speakers were invited to give a presentation based on the main theme, but from different perspectives.
After Dr. Glen Aikenhead, as IOSTE's chairman, had opened the symposium, the the first keynote speech was given by Dr. Jan Terlouw, physicist, politician and well known author of juvenile novels, whose address reflected on the symposium theme from society in a broad perspective, followed by Dr. Prins Nevhutalu, giving his view based on a society in turmoil (South Africa). As a policymaker in education a high ranking officer from the Dutch ministry of education, Mr. Mark Frequin, was invited to speak from that perspective, followed by the view of an educator, Dr. Piet Lijnse, who is a professor in the Centre for Science and Mathematics at Utrecht university.

The keynote speeches on the one hand were the trendsetting lectures for the symposium as a whole, its workshops, discussions but on the other hand exceeded this with 'an eye to the world'. They are the first part of this book.

The overall idea for the symposium was to examine the state of science and technology education in the context of the main theme and to reflect on desirable and feasible educational innovations by exchanging and discussing ideas and practical experiences. The main body of the symposium programme was organized along the lines of the two subthemes: **claims & strategies (C & S)** and **strategies and empirical evidence (S & EE).**

In making the symposium programme the two subthemes were connected to cross-curricular themes/topics, generated from grouping the submitted papers and other contributions.
This gave the following programme items:

Topic	Sub-theme: Claims & Strategies	Sub-theme: Strategies & Empirical evidence
STS-education		
- contents and teaching methods	X	X
- assessment	X	
- teacher education		X
STS cross curricular themes		
- environmental education	X	X
- national/local development	X	
- decision making		X
S\T education		
- contents and teaching methods	X	X
- teacher education	X	X
- education and industry	X	

Just over one hundred papers, together with outlines of workshops and poster presentations, formed the input for the symposium. Altogether they gave a good overview of the "state of the art" in science and technology education. The papers were put into three volumes, in alphabetic order of authors.
For an overview of the papers within the subthemes and various topics or areas of the programme, however, one needs also the programmebooklet.
Even then it is not easy to extrapolate the trends from first reading. Therefore we asked for each of the eight sections in the programme an outstanding science educator, who participated, to write a reflection on papers and sessions. This resulted in the following review papers, making the second part of this book:

Arthur Jennings	*STS-education: contents and teaching methods; assessment; teacher education - within claims & strategies*
David Cox	*STS cross curricular themes:environmental education; national\local development - within claims & strategies*
John Gilbert	*S\T-education: contents and teaching methods - within claims & strategies*
Shoshana Keiny	*S\T-education: teacher education - within claims & strategies and strategies & empirical evidence*

Uri Zoller	*STS-education: content and teaching methods, within strategies & empirical evidence*
Martha Monroe	*STS cross curricular themes: environmental education; decision making - within strategies & empirical evidence*
Reg Fleming	*S|T-education: contents and teaching methods - within strategies & empirical evidence*
Graham Mulroney	*S|T-education: education and industry*

The reviews, together with the keynotes give a clear overview of the "World Trends in Science and Technology Education" as far as was discussed at the 7th IOSTE symposium.
In order to give you a first impression of the symposium papers and the stimulating discussions that followed, we selected some of the reviewers' observations, although not quoted literally.

- Education has to play a dominant role in the responsible use of future scientific achievements (Terlouw).
- The missing link is the willingness of many countries with advanced technology to solve the problems of the third world countries (Nevhutalu).
- In fact, we have no clear guidelines to connect educational philosophy to practical educational decision making. As a result, the latter seems to be primarily a matter of taste, lobbying of pressure groups and political bargaining (Frequin).
- The underlying belief (in relation to curriculum overload - ed.) is that the ever growing amount of specific knowledge itself is not that important, as, anyhow, much of it will become obsolete rather fast. Therefore, pupils should learn the skills to acquire knowledge, as a necessary preparation for lifelong learning. Though I wholly agree with the focusing on such skills, this is no solution (follow two arguments - ed.) (Lijnse).
- The case for STS to be approached in a multi-disciplinary way suggests a unifying framework in which greater emphasis is given to the environment and the many social, economic and political issues that relate to it. Thus they propose (some presenters - ed.) the replacement of STS by STE (Jennings).
- A focus on the design, implementation, and assessment of such programs (referring to the concept of sustainable development - ed.) might in itself represent a powerful theme for a future IOSTE symposium, publication, and/or interest group Cox).
- There is some agreement (within the UK - ed.) that classroom-based research should take place. The relationship between science education and technology education within the curriculum must be explored, this being conducted with due regard to cultural sensitivities (Gilbert).
- In relation to African countries the role of the teacher has to change. Their

(presenters' - ed.) argument is that in a society-in-change, there is no room for a top-down system. Instead, a model for based on teacher participation in curriculum development processes is required (Keiny).

- However, although science and technology may be useful in establishing what we can do, neither of them (solely or jointly) can tell us what we should do (Zoller).
- Scientific facts and information may not be heavily utilized in student decision making on science-related social issues (Monroe).
- It would appear that one "world trend" is the tendency to use quantitative research designs to examine technology in STS programs. It is time to expand the research repertoire (Fleming).
- Industry represents significant human and physical resources which can add value to the education of our young people. If you accept this, the question then becomes not whether, but how education and industry can work together in partnership so that the interests and needs of all partners and most importantly our young people can be served (Mulroney).

7th Symposium Opening Address

Glen Aikenhead, chairman

The Symposium program seems to reflect four topics of concern to educators:

1. Teaching Western science and technology in non-Western cultures.
2. Integration of subject areas within science, between science and technology, and embedded in a social and technological everyday context.
3. Advances in pedagogy (a number of exciting developments).
4. Science & technology for all citizens is a guiding theme because society is demanding that science and technology education should not only be for a privileged elite, but for all citizens.

This last topic challenges educators to establish a new status quo, one based on privileging all citizens, i. e. science and technology education for all. It was this concern that motivated the birth of IOSTE in 1979, under the leadership of Dr. Charles McFadden, when the 1st Symposium was held in Halifax, Canada.
At that 1st Symposium, the following aim for IOSTE was written into the IOSTE constitution:
The International Organization for Science and Technology Education is an organization comprising individuals with the common aim of advancing the cause of education in science and technology as a vital part of the general education of the peoples of all countries. Such education should include knowledge of the fundamental concepts of science and technology, the development of scientific and technology creativity and awareness of the interrelations of science, technology and society. The Organization identifies science and technology education with the real and changing needs of humankind as a whole and with specific needs of its component communities and nations.
IOSTE has always been the collective cooperation of educators toward improving science and technology education for all peoples of the world.
That is our educational agenda. But we also have a political agenda (a political spirit). Our political agenda is quite simple to state. It is world peace. The efforts of IOSTE (to advance science and technology education for all peoples) are made in response to the demand of people all over the world for peace among neighbours, peace among tribes, peace among ethnic groups, and peace among nations. That is the demand of the citizens who IOSTE aims to serve. Therefore, IOSTE works to advance high quality science and technology education for all, for the ultimate purpose of nurturing peace among the peoples of the world.
Let me quote a Nobel Prize winner for peace, Lester B. Pearson, the Canadian diplomat who creatively envisaged the idea of UN peacekeeping forces.
Pearson once wrote:

"*How can there* be peace in the world if people don't understand one another? and how can they understand one another if they don't know each other?" The 7th Symposium program is created to get participants to know each other better. Educational ideas cannot be exchanged unless we understand the context of those ideas. How can we understand the context of new ideas in science and technology education? -- only by knowing each other personally. The secret to understanding each other was revealed by a First Nations native elder Simon Lucas, another Canadian. He said, "Without our differences, we can never know the meaning of understanding." His advice is for us to celebrate our differences rather than ignore our differences. Our mutual understanding depends on our differences, not
similarities. Our similarities make us feel comfortable, but it is our differences that lead to understanding the context of the ideas of each other. As we interact with each other at this Symposium, let us celebrate our differences, and thus explore our mutual understanding of science and technology education for the ultimate purpose of peace for all people. This is the spirit behind our efforts to improve science and technology education for all people in a society demanding peace.

Education: the key factor for the positive or negative image of science and technology in society

Jan Terlouw, The Queen's Commissioner in the province of Gelderland

Ladies and gentlemen,

May I say welcome to the Netherlands. I'm not a member of the Dutch government any more, neither am I the governor or the queen's commissioner of this province, the province of Noord Brabant, that is my colleague Mr. Houben. Nevertheless, welcome to the Netherlands, welcome to this province of Noord Brabant, and if you have some spare time go a bit north and come to Gelderland, the place were I usually am. I'm very pleased to see that this 7th IOSTE conference is taking part in the Netherlands and that you have come from some forty or so countries, as I understand from Jacques van Trommel, to spend some days here to discuss what I think is your heavy responsibility. I am very honoured that Jacques van Trommel asked me about a year ago or so, to give the first speech at your meeting. You heard that he mentioned some points of my career and you must have noticed that teaching was not part of it. I have been teaching very little thus far and so I'm actually not at all qualified to speak to you. I was a scientist for some time and I did quite a bit in politics, but not in teaching. So actually I should have said no to this invitation. But I didn't, because it gives me an opportunity to say just this one thing to you this morning and that is how heavy a responsibility you carry on your shoulders. And I shall try to elaborate a little bit upon that.

Teaching, ladies and gentlemen, is, I believe, one of the essentials of mankind, because through teaching, through telling to others what you have learned yourself, you provide continuity. Animals cannot do that. Every young animal starts anew. We don't. We can build further on what has been done before us. It is a remarkable thought that a second or third year student in physics, knows and understands more about physics than a genius like Newton did in his time. Simply because he is living so many centuries later. Simply, as since Newton there were so many physicists who have formulated new laws of nature and past on the word.
Let us never forget that the instrument by which we do this is language. And so I believe, although I was a mathematician and a physicist myself, the most important thing we teach our children is language. That is the instrument by which other subjects can be taught. And although I am now on a side path which I shall leave immediately, may I urge that when you teach your students that you are always very careful in using your mother tongue and ask from them that they use the language properly; because that is the valuable instrument we are using.

Also language is a great mystery. We don't know how we do it, we don't know how we learn it when we are young and that must intrigue you, scientists as you are.
Now IOSTE deals with teaching science and technology and is thinking about how to teach science and technology to younger and older people, to all people, as your chairman said. Let me make a first statement and that is that a teacher should be an optimist. If a teacher is not an optimist he can never convey motivation. To say this in biblical terms: there can be no faith, there can be no hope, and there can even be not love for the subject if the teacher is not an optimist. Now is it possible to be an optimist when you are teaching science and technology in an demanding society? Because we all know that science and technology have caused enormous problems. They have done much for mankind but, certainly recently, let us say this century, are causing also enormous problems. Over-population has to do with it, to just mention something. Look at the time it took for mankind, for the people on the globe to double. First it took a very long time, then came the domestication of animals and the time shortened. Next came the discovery of new continents and the doubling time shortened. Then came the industrial revolution and suddenly the doubling time of population decreased very rapidly because of science and technology. Problems we have galore and most of the time they have a strong relation with science and technology. Whether we talk about the food problem, the environmental problem, the energy problem, the armory problem we have, (we now hear of smuggling of plutonium), it all has to do with science and technology. I received a book some weeks ago, an advice to the Pugwash Council.
Some of you must know what that Pugwash organization is. It was started against nuclear armament and now is also dealing with other problems related to science and technology. The book is called "The world at the cross roads" and in the introduction the auditors Samuel Akoya and Phil Smith write, I quote: "Human kind is already a long way down the wrong fork of the cross roads", and a bit further: "in fact, disaster is not a threat in the future but is already being experienced by a great number of those now alive", and still further: "survival for all, as such is only meaningful if it carries with it the connotation of an existence that provides opportunities for all the inhabitants of the earth to live in dignity in an environment which allows for self fulfilment and creativity. Such a world must not only be equitable and liveable bust must also be sustainable over an indefinite period in the future". The book continues to discuss all these things and says: look, there are forks and cross roads, there are choices to be made, it is still possible to make the right, the proper choice and so one can be and must be optimistic. And I want to say that teaching is useless if you cannot be optimistic, a teacher must be an optimist.
I want to make a second preliminary remark and that is that I have observed that the best teachers in science and technology often get carried away by the beauty of their subject. And it is beautiful. We all know that. How beautiful the building of science is. When I studied physics, it's a long time ago, I was absolutely thrilled when I could take notice of this beautiful building, of knowledge of the laws of nature.

Later when you are involved in research, you are confronted with the disappointments you meet in your own work and the limits of the contribution you can make.
However, when teaching sciences one must not only show their beauty, but also arouse an interest in some of the pitfalls of their applications.
And so the essence of what I want to say to you this morning is, that the consequences must be taken into account also when you are teaching.
If you take an automatic riffle, it is a beautiful piece of technology. But we all know what you can do with it. If you look at nuclear reactions it is beautiful phenomenon, but we know what one can do with it, in the good sense and in the bad sense. And so we must never ignore, certainly in our days, to discuss the consequences of science and technology. For other applications than the examples I mentioned it is less evident, but nevertheless also very true. If you talk about the development of television or of sound amplification or of genetic manipulation or of polluting air jets, which brought you here, and so very many other good things, are they blessings or are they curses? It all depends on how you use them. I had a very recent experience myself. About ten days ago the retina in my left eye came down and all of a sudden, overnight, I was blind in that eye. I always had a wonderful eyesight and today exactly eight days ago they repaired it with very ingenious and refined medical technology.
Now this is a kind of technology which is not polluting, which is using much effort of men, but not very much energy. It is the kind of technology we want to spread all over the world. We want it to be available for every citizen in the world who needs it. But there are other technologies of which we have different thoughts, when we think about their applications.
Many of our problems are caused by science and technology and they must be solved by that same science and technology. Just doing away with science is no real option, it can't be done, but also we don't want it. Remember the example I just gave. So the question is, how do we make the proper choices, so that in the future the achievements of science will be used in a positive way. Here education must play a dominant role. Now before I go deeper into that, let us briefly consider where we stand with our society. Suppose, ladies and gentlemen, we make a blue print of all the worldwide problems we have. The inadequate distribution of food; the word sovereignty, as an excuse to permit mass killings when conflicts come to an outburst; the excessive use of energy per capita in the industrialized countries; the ongoing pollution and erosion of the earth. I had an opportunity last year to speak in Toronto to a man who had been in the United States teaching astronauts and he said: 15 years ago we said to the astronauts: "if you see a dust cloud over Africa, make a picture". Now we say to the astronauts: "if you see a hole in the dust cloud over Africa, try to make a picture". And he gave many more examples which show how rapidly we are going in the wrong direction in treating the earth with our achievements of science and technology.
Now let us look at some solutions. That can be done. Because the world is rich and the scientists are clever and people are inventive. One can design a world where we are solving gradually these major problems. However, if we do that, we

find that we don't have the instruments to implement the solutions. We can't enforce them. Take a simple example, a not so dangerous example, the development of the television. Suppose that when television was invented and at the point to be introduced, we would have thought about the consequences. You would said: "Oh, it gives wonderful information, amusement and whatever you have, but on the other hand it may be dangerous for children, may be they won't go out and play any more, they will be too much in front of the screen and so on". We could have tried to foresee these consequences. We might have concluded that nothing could be done about it. Because of commercial interests, interests of employment, all kinds of forces which we cannot control. Things are going their own way as a sort of autonomous development. We can say the same thing about this word 'sovereignty'. For instance, what could we do in Yugoslavia? What could we do? There are very, very few instruments we can use to do things that actually would be necessary to do. The real reason is, that it is hard for men, like for all living creatures, to look beyond his immediate interest. I think that is the deepest reason why we in fact are actually so helpless. It goes too far to go deeper into that. Conclusion is: the world can't be managed. We are not able to.

There is another factor to be mentioned and that is the rapidity of change. We are experiencing an enlargement of scale in the world. In some decades we have seen worldwide trade development in the stock markets. If New York closes, the markets open in Tokyo. We see a vivid trade all over the world of arms and drugs and other undesirable items. And at the bases of all of this is science and technology. The communication technologies, the information technologies, the transportation technologies and what have you. Rapid change.

There is another complication: the direction of the change is to a large extend unpredictable. Who could have foreseen the development of the computers in the last decades? You remember Jules Verne, the famous French writer Jules Verne, who predicted a rocket to the moon, and the submarines in the oceans. You know, did it ever occur to you that he never predicted the car? The private car which has made such an enormous impact in the world? Who could predict politically what happened in Eastern Europe, the fall of the Berlin wall in '89? And so we must conclude that because of science and technology the world is changing in a rapid and largely unpredictable way.

Secondly -apart from the blessings- there are many undesirable consequences of the products of science and technology. And thirdly we do not have the tools, the political tools, to imply the proper solutions. Rapid change, undesirable consequences and a lack of tools: you may ask, where is the optimist? I said the teacher should be an optimist, maybe a lecturer should be one as well. Where is the optimist?

Well, I think if you can't sketch a blue print, the best thing you can do is to try at least to determine a direction. And maybe that direction can be found in science and technology education, because I believe that in science and technology education we must try to find opportunities to teach the students both, the contents of science and the consequences of their applications. And so discuss with the students in the process continuously how we might direct and control

the further developments of science and technology.
May I draw the following parallel. In primitive times mankind used to live with the law of the jungle. Just the power of the strong, the survival of the fittest. And gradually and against resistance, we have made legislation to the benefit of all. It took time, it took an evolution process in which man had to learn to look beyond an immediate personal interest. Now, don't we have a similar situation with the achievements of science and technology? Immediate application of their results is our instinct, that is what we want to do. But we need to learn gradually to look beyond that and see the benefits of a more considerate enjoyment of what these magnificent scientists can bring us in the long run, when applied with wisdom and restraint.
This aspect must be an essential part of science and technology education. In order to cope with our many problems, the only hope for a new generation is that the applications of science and technology are put in more objective perspective. For taking such a new direction much discussion will be needed.
Progress in human and political sciences seems to go much slower than that in science and technology. Why is that? Is it because the latter is less difficult, or does most of the talent go to the apparently more difficult and challenging natural sciences?
It is probably some of both. I have been in science and in politics and I can assure you that however difficult physics may be, it is at least fair, it is predictable. Whereas the behaviour of people -certainly their collective behaviour- is very hard to grasp, to predict, to influence.

There is another point. The knowledge of science and technology is very specific, it is difficult to communicate, it is actually unaccessible for most people, it is in code.
Whereas politics can be understood by everyone who takes an interest in it. In relatively simple terms politics can be explained. This means that scientists cannot be innocent bystanders when leading politicians discuss the making of society: if we realize that science and technology are so dominantly present in that society. When knowledge increases, responsibility grows. Everyone with privilege to study or teach science must assume that responsibility. Let me say a word about leaders. You agree with me, I suppose, that leaders are very essential persons in our lives, whether they are in a firm or in the football team (the Americans say the soccer team) or in government or in the army. When I was in the army, drafted, I was in a company with 300 people and the company next door had only 150. Our captain was a weak man and the first lieutenant who was leading the small company was a firm, sturdy, just and strict man. One day we had a sport competition in many fields of sports and our company lost, continuously, although we were twice as large and the boys were just as healthy. We lost everything, because of the leadership of that man. You see it in physics as well. I worked in gas discharge physics for a long time and read much of the work of Langmuir.
Like other famous physicists Langmuir had a school which itself produced a new generation of very good scientists. Leadership if dealt with properly creates

quality.
Now equally important I think are the teachers. They must carry on the message. They must start the dialogue and continue the dialogue and actually they should be the best. You must have heard a thousand times the quotation by George Bernard Shaw: "Those who can do, those who can't teach." Very wrong. It should not be so. In fact every teacher should be in principle a Socrates.
What does a teacher need? He or she must be a good professional, good with people, good didactically, a good psychologist, but that in our days is not good enough. He must be a little bit like Socrates. The teacher needs to have a philosophy on society as a whole and be able to teach that and discuss that. And he needs, or she needs, to have a character which refuses to repudiate principles. That is how Socrates was, or if I may quote another brave man, Ghandi. "The best education consists of giving the best of yourself, could there be a better book than the book of humanity?"
It is an utopia I'm sketching, certainly, but something to take as a starting point instead of the: "those who cannot, teach". In my opinion even the best researchers must also teach, must have students, because research, only as a subject, destroys. Science and technology as a philosophy builds up. And a philosophy is best developed for and with students. Now this sounds idealistic, in practice we have to deal with a curriculum. That is a process of weighing and negotiating at the level of the state, the university and the school. As a simple citizen I don't hear this discussion. Although it seems of crucial importance for the future of this globe. Isn't it strange, ladies and gentlemen, that as an interested citizen I don't hear at the highest political level regularly let's say every two years or so, a discussion about what and how we should teach? Because it is so essential for the future of our society. If politicians want to talk about anything, that should be of highest priority on the list. I don't hear this discussion in the Netherlands much, probably you don't hear it in your country or perhaps you do. Tell us during the seminar. There was a writer in the Netherlands, he died about fifteen years ago I think, by the name of Vestdijk, and he wrote: "The best source of inspiration is..." I wonder what you think it is. What is the best source of inspiration? He wrote : "the best source of inspiration is conversation". And he meant also conversation with students, dialogue, the best source of inspiration.
Now how much time for communication of the science and technology you are studying, you are investigating, do you actually have in your countries? I think when I studied, maybe twice, correction, I think only once, I was given the opportunity to give a seminar, with a discussion afterwards. In all the years I studied. Once or twice, and yet the best source of inspiration is dialogue, is conversation. Communication, that is the transfer of knowledge, but it is also presenting your own opinions and discussing them with others. And since science and technology is so essential for society, this opportunity must be given. I think that in our universities science and technology students should devote about 10% of their time to learning and practising communication. Because when discussing, in the progress you discuss, exchanging views, one is building up a philosophy instead of something that destructs.

Just a brief word about the well known differences between industrialized countries and those which are less developed. I'm afraid that the latter, the under-developed countries are equally unable to manage their countries and their development as the industrialized countries are. But they have some additional problems. There is a pressure -and to some extent an urge- to imitate the industrialized countries. This often leads to the wrong priorities. For instance, insufficient use is made of the indigenous resources. The industrialized countries have an interest that some of their mistakes are not repeated elsewhere and so they urge: save your rain forests, restrain the increase of your population and so forth. Now it is clear that industrialized countries should at least take part of the financial burdens if they want this to happen. Look what they have done themselves. What we have done ourselves. In general it can be said that developing countries have the problem to find the way out of the dilemma between short term and long term interests. For the education in science and technology this means, amongst others, that the central question is to what extent in the use of indigenous sources, short term and long term interests, can be distinguished and in what way, in what careful way, use can be made of what the industrial countries have to offer.

I must come to an end ladies and gentlemen. Let me try to quickly sum up. Science is a beautiful, fascinating, inspiring, enriching subject. It is a victory of the mind, it satisfies the curiosity which makes mankind so unique in the universe. It's both logical and artistical, it's pure beauty. And technology has many of the same aspects. Besides, it has done amazing things for people in the fields of food production, health, conveniences, travel, amusement and what have you. And yet there are negative aspects and they are growing in importance. Armament, overpopulation, exhaustion of resources, lets call it pollution of the world. Gradually we have come and we are becoming aware of that. However, even if we would see the solutions, if we could know which turn to take at the cross roads, we do not have the political tools to make us take the right direction.

Your organization is dealing with the education of science and technology. You have come from all over the world to talk about science and technology education in a demanding society. You are experts, and you are kind enough to ask someone who is no expert at all in the field, to express his worries at the beginning of your seminar. I was glad to do that because you represent for me some hope. Solutions can only grow if a new young generation wants them and they can only come from that same science and technology that caused the problems. So the education of science and technology in their full magnificent, in their full danger, could be the way, must be the way. The best source of inspiration is conversation, dialogue, a meeting of ideas, an exchange of opinions, becoming aware. You will have that conversation these days and I trust you will have it at home with your students to make them aware, them and yourself, because as Gilbert wrote: "to teach is learning twice". I wish you very much success. Thank for your attention.

Co-report

Mieke Kapteijn, School of Education, Free University, Amsterdam

Ladies and Gentlemen,

I have been asked, as a co-reporter, to react to Mr. Terlouw's speech. In his lecture he stated to have a strong argument for taking in account into science education the applications of science and the consequences of science in this world. He wants us to educate responsible citizens who reflect critical, who are able and willing to take initiative and who are creative in solving problems. Scientists and also students who follow education in science and technology should become interested citizens and possibly interested politicians, who can have a say in political decisions. I want to concentrate on some of the statements and comment on the conclusions.

Firstly, he only highlighted the responsible citizen as the outcome of education in science and technology. In my view it is common sense that being critical and taking in account society's future, has to be part of science and technology education. In schools time has to be given to formulating opinions, for communication, for discussion and for decision making. To understand why it is sometimes difficult to get this on the agenda of society seriously, we have to look at various goals of science and technology education. The critical citizen is not the only goal of science and technology education. In every country science and technology education is central in the building of a skilled labour force and most of science and technology training takes place in the context of vocational training. The discussions in this conference and in the history of IOSTE stand mainly from people, what I understand of it, working in science education as part of general education. They are concerned about students who loose interest in science, they are concerned about the role that science education plays in society that are formulated, they are concerned about peace in this world as Glen Aikenhead said.
Looking through the abstracts of the papers of this conference, it was remarkable that papers on vocational training came mainly from the countries where the development of an educational system for the preparation of skilled labour is still high on the agenda. It seems to me that it is important to look at this because to get critical citizens on the agenda of science and technology education and to get money to work on it, a skilled labour force in my opinion is a condition. A skilled labour force will always have priority above getting critical citizens in a society. What we see, that different societies have different priorities in their science and technology education. I think it's important in this conference to discuss what the

implications are when science and technology still has to give a lot of attention to the preparation of the labour force.

A second point I want to make is about the operationalization and implementation of the science education for critical citizens. Mr.Terlouw sketched already an utopian teacher that will be able to teach with new content. I think it's very important, and I think in the whole conference we see a lot examples before having any impact in education their should be curricula and their should be teacher training. Otherwise no large scale implementation and institutionalization can take place. In my experiences of the last years it is very important that when you want to train teachers to teach something, that you don't ask from them to be the excellent teacher. Because most people are not Socrates, are not always optimistic are not always carried away with the beauty of the discipline. I think in teacher training, if you really want all the teachers to share your thoughts and to implement new directions, you have to have very concrete materials to make clear what they have to do in the classroom. What the pupils have to do, what the students have to do and what the teachers have to do. And if the operationalization is not concrete enough, only a few teachers let themselves inspire by the stories, by the tales, by the ideas that are in teacher training. It is not so difficult to inspire 20% of the teachers, but it's very difficult to get the other 80% over the hurdle of implementing some change. The last remark I might have is on the difference between developing countries and industrialized countries. I think Mr.Terlouw mentioned that the developing countries should find a way out of the short term and long term interest in the countries in the use of indigenous resources. I think there is no difference in the responsibility between the western world and industrialized world and the developing countries because the western world is using most of the indigenous resources that are available in developing countries. So it is their problem as much and it may be more than the problem of the developing countries. Thank you.

A case from a world in turmoil

Prins Nevhutalu, Foundation for Research and Development, South Africa

Mr Chairperson, honourable quests, participants, comrades, ladies and gentlemen. It is indeed an honour for me to be invited to address this 7th IOSTE Conference on Science and Technology Education.
I would first like to extend my sincere gratitude for the invitation to the organisers and specifically to Mr. Jacques van Trommel who first contacted me in South Africa. I also want to extend my sincere, special thanks to all the people here who have supported our struggle during the previous years of apartheid. Thank you very much. South African black people owe so much to you, for all your efforts during the dark days of apartheid. Your relentless support, materially and morally have been so instrumental in bringing the apartheid regime to its knees. We could not have done it without your support.

I want to share with you a perspective of my country from the point of view of a scientist and that of a man who has been deprived of his basic freedom and rights since birth, who has gone through the system of apartheid schooling, but managed to escape the ultimate fate of hopelessness and despair that many of my fellow brothers and sisters suffered. This perspective may be characterised by excitement and hope for the new opportunities that my freedom presents for me and the rest of my people, at the same time, by anxieties stemming from attempts to perpetuate the statues quo under the guise of democracy, so much has changed and yet nothing seems to have changed. A few years ago I could have been standing here making a call for the international community to come to our assistance to help dismantle the evil system of apartheid. Today I stand in front of you to make another call for help to redress and correct the backlog of many years of systematic underdevelopment and in particular to ensure that this fragile democratic system becomes successful. South Africa is not the first African country to gain independence.

Science and Technology Education in a demanding society, is the theme of deliberations. It is indeed a relevant topic not only for South Africa, but for the whole world. It is a daunting task or a challenge for many of us and to make science and technology serve the good of mankind. In your deliberations it may be important to interrogate intimately the meaning of a demanding society of more appropriately what are the demands of a society. You could extend your analysis to define clearly which societies you refer to. You may want to ensure that Science and Technology does not stay a terrain of western world and dominated by white males. The challenge is for science and technology for all

citizens by the year 2001+.

Science and Technology are the mother source of new ways to do things and to create new kinds of goods and services, new ways to satisfy the seemingly infinite human inspirations and therefore to expand opportunities. Technology enables us to do more things with fewer people and hence improve our life. Science and Technology has had different kind of applications, chief of which were for medical, political and military superiority. One of the debates in South Africa is the issue of our arms export, and wether our country should continue to export some of the very harmful weapons into the rest of Africa. It is an embarrassment to our government to discover that weapons from South Africa were used in Ruanda, in Angola and Mozambique. Military technology has been used for a long period as a political bargaining tool and to destroy nations. In this competitive world, it is not only the strongest that survives, but the one with a more advanced and powerful technology who becomes the strongest. It is perhaps too early to forget the cold war which preoccupied the most powerful nations in the world. A typical example of an obsession of mankind with the military power of science and technology. If such a kind of obsession were to be directed in finding solutions to some of the basic demands of our society, I am certain some catastrophes of this world could be avoided. I want to challenge you today, that you must resolve after this meeting to mobilise all resources human, scientific and technology, call expertise and material to provide food for the poor nations of the world. I can assure you that if you are really committed to that goal, within five years the goal can be realised. The missing link in my opinion is the willingness of many countries with advanced technology to solve the problems of the third world countries. It is by no accidents that today we have third world countries and first world countries. One of those worlds has been allowed to exist because the other does also, and they are connected. You cannot have a first world country unless you have a third world. In the same vein, it will also take commitment from people and their scientific and technological inventions to bridge the gap between the third world and first world thus creating unified world. Demands that span across the nations are peace, a sustainable environment, food, health care, shelter and education. It is my thesis that with the present scientific and technological expertise some of these basic human rights can be realized in the nearest future. It is a myopic view to consider only those issues that directly affect my country, as being relevant for my attention. "As long as Holland has enough cheese and water, why should we care about Mozambique?"

The issue of air pollution, which threatens human species by destroying the ozone layer is a typical example of how everyone can join to create a better world for us all. Air pollution has received attention from the world superpowers because it was not only threatening Mozambique citizens but the whole world. If such an attitude could be extended to other societal basic needs, I am sure the world will soon become a more pleasurable place to live for everyone of us. IOSTE must take science attitude as zero-sum. a game that the first world can

only gain if the third world survives. It is anti-science and anti-technology if the first world can only gain at the expense or loss of the third world. Isn't science and technology about the ceaseless quest for understanding the solutions, our universe and creativity of humankind? It is IOSTE's responsibility, ladies and gentlemen, to create one world through Science and Technology for the benefit of all.

The title of my talk is "A case from the world in turmoil", which fits snugly in the theme of your conference. To give structure to my address I will attempt to answer the following questions:

1. Why should South Africa which has just experienced full suffrage be in turmoil?
2. Why should I, a black person, who should be excited about the promising and bright future talk turmoil?
3. What is the connection with South African with Science and Technology?
4. What role can you individually and collectively as IOSTE contribute to tranquillity and hope for the majority of South Africans?

My presentation is by no means exhaustive and many of you may have many questions that touch other areas not covered in this speech. I will try to brief to give you more time for such an interactive session.

Ladies and gentleman, our country has had a relatively peaceful transition to democracy, but I am convinced the country needs revolutionary strategies to address to backlog of the past 50 years. South Africa consists of two worlds apart. The first world with all its modern infrastructure and opportunities. This is a world where the minority white people live. It is a world characterised by posh houses, excellent roads and all the other good attributes of the first world. It is by no accident that this first world came about. The South African economy and its political system was designed to the few white minority. It used the labour of the black majority to service this economy without the majority accruing any benefits from it. Our people have been digging gold, diamonds, provided cheap labour for building this infrastructure and working in farms without any reward for them. If the black majority had kept silent and never wanted a piece of the pie, perhaps the system would have continued unchallenged. It was only when the black majority started to demand part of the pie, that the economy could no longer cope with the additional demands and could not be sustainable.
The system was designed to address the needs of the minority white people and excluded the majority of the black people and hence it collapsed. What does this mean for a new democratic government? It means that the new Government of National Unity should not use the Apartheid economic policy framework to make the economy benefit the whole nation. A reformed economic policy would only serve to perpetuate the social dichotomy in South Africa. What the country needs is a completely new economic system that would not only create wealth for the nation but also contribute to redressing the past imbalances. South Africa has

one of the greatest opportunities, to create everything afresh do the right things correctly. The greatest challenge of the new government in the few months in office, is the formulation of new economic policy framework for social transformation. Even though apartheid was a human scourge, it has built a wonderful infrastructure that is the envy of many African countries and this infrastructure must serve as a foundation for future plans.
To kick start the economy in the short term that would begin to provide basic needs for the black majority, the government has developed a Reconstruction and Development Plan or RDP, as it is popularly known as the RDP. The plan is intended to mobilize all resources for rebuilding the country bruised and battered by the apartheid regime. The plan advocates a leading role by the state, a thriving private sector, and an active involvement by all sectors of civil society. It is a people driven process that focuses on the following issues: Meeting in the short term, basic needs, developing human resources, building the economy and democratization of the state and society. This plan was developed by the ANC before it came to power. The first hurdle for the ANC was to make the RDP a government programme with support from business and other political parties. Though RDP has been promoted successfully to the nation in general, there still remains an unwillingness by the old bureaucracy to implement the plan. A change of mind set needs to occur in the civil service to ensure that the RDP becomes a success. So far reports from some government, development agencies not only indicate an unwillingness to participate in the RDP, but a strategic attempt to sabotage the implementation of the RDP. The RDP plan sets out specific objectives and even provides specific output products such as houses, roads, services, electrification of townships and telecommunication for all by 1998. To that end the government has set aside a separate ministry and a separate budget. Unless the total budget of the next five years is dedicated to the RDP, the small side budget allocated in 1995 will not be able to meet the needs of the majority.

What has Science and Technology got to do with the RDP?
South Africa has been dubbed the Japan of Africa. For such a prophecy to become a reality, the country has to learn from the Japanese experiment. South Africa is not the first country to gain independence, many have gone before us but there are no tangible gains visible.
Science and Technology is an instrument of change. Science and Technology is a key component in both the industrial strategy and provision of high quality infrastructure and services. Unless the RDP is premised on a science and technology base it will not be able to deliver the expected outputs. If our industry and the whole economy is not led by science and technology, then it will not be competitive and sustainable. Those who designed the guiding principles of RDP did not place S & T as a central driving force of the provision of basic needs. One of the main provisions of the RDP is job creation, that is using labour intensive projects. Is science and technology incompatible with job creation? Our challenge is to use S & T not to just create jobs but to create quality jobs. I believe that what lies ahead of the technology rainbow is not unemployment but quality jobs, wealth creation and quality life for most of our citizens. Do we have such a S & T

base in South Africa
South Africa boasts a fine, highly advanced science base; National research facilities such as the National Accelerator Centre. Astronomical Observatories, Science Councils and associations, museums, some of the departments of science and engineering at universities, technicians and some of the best internationally rated scientists. If you remember a recent event about Comet Shoemaker; South Africa provided one of the best observation facilities for the world to watch when Jupiter was hit by the comet. The first world heart transplant was performed by one of our own, Chris Barnard, in one of our hospitals.
Last year South Africa admitted that it produced a bomb or has the capacity to produce one. Can South Africa afford it?
Mr. Chairpresident, these accomplishments are punctuated by the shameful footnote: that these have not been to the benefit of the majority of our population. In spite of these advances the majority of our people are ill-educated, have no houses and lack the bare necessities and infrastructure. In the land of heart transplants, our infant-mortality rate is shockingly high. In the land of the Atomic Energy Corporations, 80% of our people lack electricity and water. The previous government sanctified science as a territory of white males only. It is by no accident that today in our conference I am the only black person from South Africa. Science and Technology was a no go area for many of us. What then?
The greatest challenge for the new government, is to harness the wealth and knowledge and technology from the S & T infrastructure for the benefit of the majority. It therefore means first that the infrastructure and expertise, although it may be viewed by many of my group as racist and representing the past, must be maintained at all costs. Secondly, we don't just maintain it, but it must form a foundation in the provision of our basic needs. Thirdly it must be used as a tool of empowerment of our people by making sure that more and more of the majority are trained in S & T. The country must begin to transfer some of our best technologies from covert military use to civilian use. Our defence industry has some of the most sophisticated communication technologies in the world, and if such expertise is converted for the benefit of our large rural communities, the goals of the RDP can be realised sooner.
Education and Training in Science and Technology of the majority will be one of the majority of the mechanisms of empowering the majority to enable them to participate fully in the economy as equals. This places and unprecedented burden on the higher education system which was also an exclusive area of white people. The previous ten years after the opening of all universities to all races has resulted in very little change, the white universities which offer engineering studies continue to produce white graduates. The number of national graduates in Science, Engineering and Technology for 1993 has dropped tremendously. This is the time when the country needs more engineers and not sociologists.
Many of the problems originate from the need to protect the status quo, but largely from the poor pretendary training of black children. The previous government successfully excluded us from quality education by feeding us gutter education. Science and mathematics were not offered in many schools. The

number of teachers qualified to teach mathematics and science remains very low today. The facilities, classrooms and laboratories are in a state of shambles. For the first time the new government is committed to unitary system of education. Education will be free and compulsory for the first ten years of schooling. Parents will have to pay for the last two years of high school. What is so interesting about the education policy recommendation is the fact that for the first time every one will have to study mathematics and science in compulsory years. A proper analysis of this policy recommendation reveals lack of provision for qualified science and mathematic teachers. How can we correct the past imbalances by failing to make provision for the new dispensation. The plan boasts of introducing technology education at all schools. This is indeed ambitious, but not impossible to achieve. But such a plan should be preceded by retraining of the existing teachers to ensure that technology as a subject is offered by competent teachers. The task that lies ahead for the new education ministry is enormous. Education is one of the most effective tools used by the previous regime to keep us for ever subjugated. The present education structures consist of 19 education departments which have to be rationalised into a single department. If time was at side of the new government, perhaps I would say it would be able to fundamentally change the system. The voters demand changes immediately and that must come in the form of an improvement in matric results. They want to see classrooms with facilities, schools with electricity and water and most importantly a cohort of qualified teachers. They want to see a new unifying curriculum which they must participate in its development. Most of these expectations cannot be produced overnight. Rather than adapting a defeatist attitude, what alternative approach can we utilize to supplement the existing capacity is South Africa? What about the role of technology as a subject as schools? The new government needs to prioritise the needs and systematically work towards in their fulfilment. It must also realise the value of using technology in the interim to catchup on the existing backlogs.

So far the students are attending school, very minimal disruptions and hopefully the country will reap the dividends of this tranquillity. The problem of adult basic education, vocational skills and labour training also requires governments attention. Of most importance, the issue of marginalised youth who left schooling in the eighties also needs an immediate attention.

I have presented you with a synopsis of the situation of my country, I strongly believe that we are going to overcome these obstacles. The world has been supporting us to remove apartheid and I am sure your countries will ensure that the victims of apartheid are empowered sufficiently to be able to fend for themselves. You cannot save us and then leave us to die. I am certain that goodwill will prevail from you here and from your governments and will you join our government to make sure that this experiment works.

In conclusion, how can you as an individual contribute to the success of the government?

1. Give advice from your own experience.
2. Availing yourself and your infrastructure to train black South Africans in your institutions.
3. Come to South Africa to teach at high schools and universities.
4. Form networks or collaborate with South Africans.
5. Make your science and technology available for our use in the educational system and setting up the new structures.

Mr Chairperson, ladies and gentlemen, if you think that the struggle for South Africa is over, I can tell you that it has just begun. The apartheid system has produced illiteracy, hunger, disease, homelessness and drug addiction. I want to invite you ladies and gentlemen, to join me and my fellow citizens to cradicate these evils from our country. Thank you.

Co-report

Mieke Kapteijn, School of Education, Free University, Amsterdam

"... we should celebrate our differences in order to create understanding." I think that the speech of mr. Nevhutalu made it possible to begin to celebrate the differences in a very concrete way:

- the slides that show the beauty of South Africa,
- the figures that were shown clarify the results of apartheid in relation to the level of training and professionalism very clearly,
- and his concerns about the struggle that is just starting in South Africa at the moment.

From the jubilant days of the elections at the time, these elections were there also in Swaziland and it was very good to see what happened. Now the implementation of how the plans have to be realized. And what I think very inspiring is, that there is a lot of optimism about what can be done. I think that one of the differences between what we experience in Holland and in a lot of the western world, is the experience that you cannot expect real development in society why we don't have the instruments. That we don't have the tools to make great and fundamental changes is something Mr. Terlouw this morning stated. I argue that in relation to South Africa as I see as very inspiring developments in South Africa due to the determination and the working together of people who really want to change society. Something changed already and it happened peacefully. And in my view they deserve a worldwide support to the developments that are taking place at the moment. One of the things I did before preparing myself for this co-report was reading some of the research that was done previous to make changes in education and especially education in science and technology. And I was impressed by what people try to change in that society. What is changing in my country in education is peanuts compared to what has to be changed in South Africa. The determination, I think, is something that I really adore. If you see that from the nineteen departments that we mentioned one education department has to be made. The departments vary a lot in culture and have very different qualifications. The curriculum has to change, there has to be one qualification system. The training of teachers has to change, as well as the infrastructure and equipment and not to forget the training of schoolleaders. I'm convinced that through all these changes automatically changes in decision making take place as decisions up to now were made only by the white government and now a lot of other people have to be included in the decision making process. Altogether it gives the feeling of hope of creating a new world but it also give the feeling of "Oh this is really only the beginning"; a lot has to be done and a number of risks have to be taken and a lot of people will

stay in their present situation for a long time before it comes to the results that are aimed. Mr. Nevhutalu in the end gave some concrete ideas about what we can do as an organization, what we can do as an individual. And I can assure you from my experience in Southern Africa that it is very worthwhile to be there, to teach there; teaching in a so different society makes also clear to yourself what your own society is. That helps you to develop your own ideas about education and it is also worthwhile I think because people are really very eager to get education. It is a pleasure to teach in an African school. I don't know if there are opportunities during this conference to make really concrete, how things could be organized, but I think it important for IOSTE to think about concrete advices and concrete communication. I'll think that is what I wanted to say about it. Thank you.

Education in a changing world, seen through the eyes of a policy maker

Mark Frequin, Ministry of Education and Sciences

0. Educational strategy

Can education respond to the changes taking place in society? Of course it can! It does and it must!
The question, however, is how it can best do so. What strategy should be adopted to this end?
In this contribution, I shall attempt to outline the main features of such a strategy. In doing so, I shall be looking at things with the eyes of a policy maker - a policy maker who is keen to turn the changes taking place within society into an effective approach to education. And the first step towards effectiveness is to identify those changes which are most relevant in terms of the challenge they pose to the education system.

1. The challenge to education

In broad terms, the education system is being asked:
a. To respond to the growing complexity of the world.
b. To take account of increasing problems.

Society is becoming more complex and less one-dimensional. The mental world in which each of us lives is continually expanding. It is no longer confined. Life is no longer lived in the home village or the home town, within a familiar world of limited friendships and family relationships. The whole world is our oyster.
The technological possibilities are immense. Contact with other cultures is now a matter of course.
This means greater opportunities, more factors to be considered and more choices to be made: in short, greater complexity.

It is not only complexity that is increasing. The problems are also multiplying - not only problems like environmental pollution, unemployment, war, violence and threats to public safety, but also difficulties within the family and health issues. The problems also seem to be getting more complicated all the time.
Many of these problems are eventually referred to the education system. We are asked to provide a response to the problems of society at large.

education Education appears to be seen as <u>the</u> answer to a host of social issues. In view of the complexity and scope of the problems involved, this is an almost impossibly tall order.

2. Context

The task of meeting this challenge to the system seems fairly ill-fated from the start.
For example:

a. Education has to compete with things like television, dancing, music, house parties, Nintendo ... all things that are far more attractive than school work. Young people are more preoccupied with disco's than with education in the narrow sense. These things are all much more interesting.
b. Values and standards are changing. They may even be disappearing. At least, so it is increasingly being claimed. Leaving aside the question of whether this is actually true, what is quite clear is that we can no longer take values for granted. This makes it more difficult to identify the purpose of education, either for society or for the individual.
c. There is increasing cultural diversity. From the more or less 'one-dimensional' cultural environment of the past, we are moving in the direction of multiformity. Society is less and less of a melting pot. As a result, fixed standards are being replaced by diversity.
d. Finally, there are increasing restrictions on the amount of money available for investment in education. Almost all over the world, cuts in education are the order of the day and spending priorities are having to be carefully considered.

EDUCATION

These examples illustrate the fact that it is increasingly difficult for the education system to address the issue of social change, and yet increasingly necessary for it to do so.

3. From challenge to strategy

Given the challenge being posed by society, I would formulate three questions to help us decide what educational strategy is required in a changing world.

a. What needs to be learned?
b. How does it need to be learned?
c. When does it need to be learned?

Simple enough questions, but perhaps not so easy to answer.

a. **What should be learned?**
   Obvious trends are that:
   - more needs to be learned and
   - more is involved than just knowledge.

   In the course of this conference on science and technology, it has already become clear that schoolchildren/students are facing such widely varying issues as democracy, electronic highways, sex, genetics and hunger. A multitude of highly diverse topics. This is not surprising in view of the complexity I was just talking about. This is putting pressure on education to deal with an increasing range of topics.

The traditional response would be to include more subjects in the curriculum. But this is no longer an option. There are already so many subjects to be taught. The curriculum is already fully stretched. We have to look for different approaches: for example, through combining subjects, through project-based learning, integrating topics within existing subject areas or allowing less time for each subject (greater efficiency). The task is to teach more topics in the same amount of time, and to help children find their way in a world of rapidly changing issues.
An example of this kind of approach would be to teach science (and technology) in a foreign language. For example, in Dutch schools we could use French as the language of instruction for physics.

> In considering 'what should be learned', we are concerned not just with knowledge. In the Netherlands we use the three key terms "head, heart and hands". By this we mean that it is not only knowledge, but also attitudes and skills that are relevant. We aim to achieve a combination of the three.

Skills are important. In the first place, of course, because the education system is training people for the labour market, where a variety of skills are required, both social and technical. But social skills are also essential in their own right. They are tools to allow people to function in society. For example, in the school context pupils are still dealt with largely as individuals, while in the outside world the main requirement is for teamwork and social integration. This is something that has to be learned. (Of course, both in and out of school.)
Moreover, 'knowledge' and 'skills' must not be seen in isolation from attitudes. Feelings and thoughts are involved, and 'knowledge' and 'skills' are not enough without the right 'attitudes'. If you're dealing with technological innovation, you can't ignore ethical issues. The debate going on in the Netherlands about the (technically impressive) bull Herman illustrates this point.

b. **How should it be learned?**
Given that society is undergoing rapid change, is highly complex and faces a multitude of problems, it is impossible to tackle all these issues within education. What people need is the ability constantly to adjust to new developments, to continue learning and changing.
This means that the ability to learn is more important than the knowledge itself: it is a matter of learning to learn. The experience of the universities shows that this is no easy matter. Students have no lack of knowledge. The problem is rather their lack of learning ability.

A second concept is learning by doing. For many people, this is a highly effective form of learning. I saw an example of it in a school in the south of the Netherlands, where the children were having great difficulty with maths. Until the day when the teacher suggested that the class should soup up a motorbike. The class proved instantly capable of mastering a large number of mathematical principles. Similarly, forms of education in Germany and in the Netherlands where theoretical teaching is combined with on-the-job training show that learning by doing is highly effective.
Not only that, but it often makes education much more fun.

And it would certainly do no harm to make education more fun. There is a great deal to be learned from television, computer games and sport. What's stopping us from making education just as much fun as discos or house parties, and just as exciting as computer games or sports matches? Let's turn education into a treat again. We can do that by using technological aids. The new technologies are major tools for tailoring education more closely to the individual: the aim is 'independent learning'; education that responds to the abilities and desires of the individual.

c. **When should it be learned?**
Three ideas seem to me to be relevant here.

- An early start:
  Around the world, education is increasingly starting early. At the age of 3 or 4, or even before that. New Zealand, for instance, has had encouraging experience in this area.
- Learning in the workplace:
  Learning takes place both in and out of school. Including in the workplace - and, in fact, at work more than anywhere else. Work is a constant process of learning. This means that learning cannot and must not stop when young people leave school and go out to work.
- Life-long learning:
  In view of the complexity of society, we should not expect to have finished our education when we leave school. Learning is a non-stop process, and our educational strategy must respond to this fact.

4. Strategy

Given these ideas and thoughts about 'what should be learned', 'how it should be learned' and 'when it should be learned', there are a number of strategies that can be employed to cope with a changing world. These are strategies at varying levels. I shall pinpoint a number of those which are relevant in the eyes of policy makers. The choice of strategy will, of course, be subject to time and place.

student teacher school family industry government

a. Pupil/student level:
Schoolchildren/ students must take individual responsibility for their own learning. A more structured approach in the beginning can give way to more individual organization of learning later. This opens the way to the exploitation of the right moments to learn, to life-long learning, to customized courses and to the possibility of tailoring provision to meet individual interests and concerns. 'Self learning' must enable young people (and eventually also adults) to respond to a changing world.

b. Teacher level:
The teacher is an extremely important figure in the education of young people (and, indeed, adults). The teacher is vital to and within the learning process. The problem is that teachers do not always enable pupils to learn for themselves. To quote one Dutch university professor: every minute that a teacher is talking is a minute when the student is not learning. The aim is for the teacher to enable pupils to learn for themselves. The teacher must more frequently assume the role of the mentor or coach.

c. School level:
All over the world, there is a trend towards giving schools greater freedom. Towards enabling schools to organize the learning process for themselves (given, of course, certain social aims or criteria). Schools are made up of professionals. Teachers have been trained to assist the learning of children/young people. They must be given the freedom to do so. Teaching is an occupation that requires freedom. But freedom must be balanced by responsibility. School autonomy does not mean the complete absence of obligations.

d.. Family level:
Education, or rather learning, does not end at school and it does not begin there. What is learnt in school is part of a more general process of development. There is broader context in which learning takes place.

Parents bring up children and help them learn. It is parents who, in the first instance, determine the child's route through the education system. Schools are in fact there to serve the wishes of the parents. Accordingly, they should see parents more as their clients. The (professional) school is providing an 'educational service'. Seeing things this way can also help to achieve coordination with - or within - the overall learning process. Of course, as children grow older, they will themselves take over the role of the parents. From that moment on, they continue to build upon the values and norms inculcated by the family.

e. Industry level:
Schools educate young people eventually to enter the world of work. It is important that there should be a smooth transition between education and work. It can be helpful to involve employers in school-based learning: for example, by negotiating agreements with them about the knowledge and skills young people need to possess (curriculum content), about the form of examinations, about academic and career profiles, and about on-the-job training (to supplement academic courses ...).

f. Government level:
At the end of the day, it is government that translates the wishes or demands of society into an education system, into quality criteria and into the evaluation of the learning process and its results. While paying due regard to the freedom which schoolchildren/students, teachers, employers and parents all need to achieve a proper learning process, government must nevertheless keep a constant sharp eye on the needs of society.

As I said earlier, this is no easy task, given the changes now taking place in society. And that brings us right back where we started.

Co-report

George Za'rour, The World Bank

I am very glad that I did not miss this Symposium. With my type of work at the World Bank, it is difficult to plan trips and missions because timing is influenced by "policy-makers" on both sides of the fence, the government's and the Bank's. May be this promotes my qualifications to comment on the thought-provoking presentation of Mr. Frequin, a policy-maker. It is only fair to point out that I received an outline or an abstract of the speech two days ago while I was in Amsterdam. Of course, for some the outline can be of no importance because many reviewers or co-reporters often end up giving a totally new speech, only remotely related to the speech under review.

In most developing countries and some developed countries, the policy-maker is the government. Unfortunately, everybody feels that he/she knows enough about education that they will not hesitate to express opinions or even influence policies, if they are in a position to do so. May be because people have spent so many years in formal schooling and their children are still attending school, they feel qualified in this sector. From another angle, I was struck by an observation of a high Ministry of Education official who told me last week that their educational system had the best developments and changes when the Minister of Education was least qualified in the education field; that is, when he had never before worked in the sector. This should make our speaker, Mr. Frequin, feel good. For a non-educator, he certainly gave us lots of good material or food for analysis and thought.

Often the policy-maker is the one with power or the one who is perceived to be powerful. In one country, a centre for educational research and development was established. It practically stripped the Ministry of Education from all significant powers and functions. The president of the centre was strongly backed by the president of the republic. As soon as the term of the resident of the republic ended, the president of the centre went looking for another position outside the country and appointed a rather weak acting president.
The policy changes were shaken from their roots because they were not deep-rooted.

I agree with Mr. Frequin's observation that society is becoming increasingly complex. The educational implications are that we need to prepare our students to adapt to continuous change, to provide them with survival skills to be able and willing to learn new things and developments. It seems that there is an agreement

on this goal, but we disagree on the "what", "how" and "when" to learn. Or may be "disagree" is not the appropriate term.
We do not seem to know optimal answers or specific strategies to respond to these questions. I should also add that answers are not the same for all countries.

Mr. Frequin describes the first two theses in his presentation about the role of education to solve societal problems and about the circumstances for education, he describes them as "mission impossible". On my part, I look at the tasks facing us as educators to be covering a wide spectrum with desired goals at the end of the spectrum. We strive to move towards achieving those goals, and we do so to varying degrees of success. Although it is practically impossible to have everybody reach the end of the spectrum, we have to keep moving in the right direction even though the goals themselves are subject to change with time.

In the section of "what to learn", our speaker states that "there is a general understanding that science and technology are important subjects" and then he proposes that consideration should be given to combine science and another subject, may be language.
Presumably, if each subject alone gets say five hours a week, or ten hours for both, then both combined can be given seven or eight hours a week. Thus, you reduce the enormous pressure on the overloaded curriculum. Irrespective of whether I do concur with the claim about the importance of science or not, I do not agree that the proposed strategy addresses the claim. It will be more appropriate to combine or reduce time of subjects deemed to be of less importance.

With respect to individualism versus cooperation; it is a dilemma. Labour market economies which are expanding all over the world focus on competitiveness. You know that most industrialized countries are trying to improve the quality of their products in order to be competitive. In several ways, we reward the best team and the best individual in a team.
How do we prepare students to live in an competitive world and stress cooperation in school?
This is only one of the issues facing us that we need to find a solution for.

The emphasis on "learning by doing" should be welcome among a group a science and technology educators. However, I claim that in many countries, we only pay lip service to this principle and we are not doing a good job at it. We also still need to know much more about how to realize the goal: to know how to learn. How do we teach children "how to learn"? We assume that it is a by-product of what we do in the classroom or school. Aren't there better ways to achieve it? We should also provide students and school with the tools -the facilities and technology such as library books, computers and software- to enable students to learn on their own. Regarding "when to learn?", there is a saying in Arabic (may be some of you think it is a saying originating in English) which translates into: seek knowledge from cradle to gravel.

Mr. Frequin is advocating something similar; he says starting at three, but he mentioned even before birth. He also states that it should be relevant to one's work and the labour market.

How should we make education more attractive? I agree that probably we are not tapping the variety of interests and inclinations that attract the attention of youth and motivate them. If we can teach through the medium of sports and computer games, why not? But it is easier said than achieved. About 20 years ago, I was a luncheon speaker in a meeting of administrators of community colleges near Miami, Florida. The theme of the meeting was "Community Colleges for Internal Cooperation". I suggested that one way for the US to go metric is to change their measuring of the football (American) field from yards to meters. I even suggested that when they change the 100 yards into 91.5 meters, they can have a neutral zone in the middle, 1.5 meters wide. Anyhow, as you know it did not work and they are still dealing with the problem unsuccessfully.

In discussing better strategies at different levels, our speaker states that our teacners are professionals. May be in Holland and Germany, teachers probably do have the facilities, compensation and education that can help make them professionals. But, this is not the case in many developing countries. How can they be professional, when their salaries are minimal and they have to rush to other jobs even while the bell is still ringing? A generation ago, in many developing countries, top students used to be attracted to teaching by fellowships. Now, it is a bottom priority. Imagine hearing stories of teachers who do not teach well in class so that there will be a demand for private tutoring of their own students.
What kind of professionalism is this?

In conclusion, let me state that often policy-makers are in ivory towers away from the field or the schools where the challenges are being faced. It is my contention that if we do not pay attention to the role of the teachers and principals in implementing policy at the schools level; then our policies, no matter how lofty, will not be applied the way they were intended. Teachers and school principals are a group of potential "policy breakers" and policy-makers should strive to make them their allies by considering their views and involving them in the process of policy making. Thank you.

Innovations in science education and evidence from classroom learning

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1. Introduction

First, two remarks to start with. Being Dutch, my experience in our field is largely restricted to Dutch circumstances. In the following I will therefore mainly draw on Dutch examples. However, these may function, I hope, as useful case studies, though unavoidably leaving an important transfer step to be made by the reader. Secondly, being a physics educator, the following will be strongly biased from the perspective of secondary physics education, asking for another transfer step of the reader.

Within their main theme of 'Science and Technology Education in a Demanding Society', the organisers have asked me to focus on 'strategies and empirical evidence'. They described this subtheme as: dealing with the connection between strategies and goals for educational innovation, the effectiveness of those strategies, and classroom reality, in particular: classroom R&D on learning effects.

Or, as they explained more informally: to what extent has research shown that all those innovations that have been and are advocated by educational policy makers, educationalists and science educators really lead to more effective learning in the classroom.

Others have written about the importance of science and technology for our future society (see, e.g, Terlouw, 1994). From this importance, the necessity of up to date high quality education in science and technology is self evident. Not only because of the need of a sufficiently large and highly qualified workforce, but also in view of a well educated citizenry. As far as this is concerned, I need not go into further detail, as I assume that all of you know the relevant rhetoric. Apart from mentioning that, at least in western countries, a supposed and sometimes apparent insufficient interest of pupils for science and technology seems to be the basic economic driving force behind many, if not most, innovations in our field of education.

Now, what kind of innovations are we actually talking about? Though it is difficult to make clear categories, I think we may distinguish between:

1. innovations that focus on the introduction of new subjects for a particular school system;
2. innovations that focus on changes in curriculum content for a particular subject;

3. innovations that focus on new ways of teaching a particular curriculum content.

Thinking in retrospect about effectiveness of implementations, these categories may make sense. The first two categories do not seem to have that much to do with classroom research on teaching and learning, in contrast to the third. However, I will argue that this relation should be much more intricate than it seems to be at present.

2. New subjects?

Major innovations at the school-curriculum level often ask, at first, for intensive debates about whether or not new subjects are needed, or whether incorporation into already existing school subjects will be sufficient. As from a policy-maker's point of view, there's certainly an end to introducing ever more subjects (Frequent, 1994). Such debates deal with all kinds of social, pedagogical, psychological and economic arguments, but results of research on classroom learning hardly play a role in them.

In The Netherlands, debates have been or are going on, e.g, with respect to subjects like environmental education, technology education, education in computer science and information technology, and health education (peace education is no real issue in our country). In other countries, similar debates have been or are taking place. Regarding general education, they deal, in principle, with the basic question of whether an education that is structured in accordance to traditional science disciplines, such as physics, chemistry, biology, can still deal appropriately with present day and future demands of society.

Introducing new school subjects in the compulsory school curriculum, means a major change, that is often closely linked to changes in the school system as a whole. Decisions about such innovations are usually taken at the level of the Ministries of Education. Therefore, a basic inherent problem is that they are in strategy essentially top down. Decisions on content and goals are usually taken before it has been shown to what extent they can be taught realistically.
To give an example, in the Netherlands, after more than twenty years of political debate about whether or not 'going comprehensive', as a compromise, a new core curriculum for the 12-15 age range has been introduced within the existing school system. Thus new subjects, like technology, computer science, health care and integrated chemistry and physics, the latter to replace the till then separately taught subjects, have now got a place in our schools.
Once such a decision has been taken the implementation is a matter of course, as all schools have to teach the core curriculum from a certain set date. So from a policy maker's perspective it concerns an effective innovation, but when we look at the actual classroom practices, the situation may be rather different. The number of schools, e.g., where physics and chemistry will really be taught as one integrated subject, instead of being taught in a way that remains much closer to what has been usual, will be considerable. Its full integration will probably take years of slow gradual change.

Thus demonstrating a well known inertia of people to adopt changes they themselves have not asked for.

As a follow up to this core curriculum, a ministerial steering group is now organising a reorganisation of our upper level secondary school curriculum as well. Restricting myself to science and technology, the difference between educational rhetoric and political practice is again striking. Of course we, as educators, may write about the importance and nature of technology and how it differs from science (e.g., Layton, 1992) relating it to consequences for teaching. Or about the importance of teaching about the environment and of the value of computer literacy for future citizens. But how does such writing translate into school subjects, numbers of lessons on the timetable, and teachable curricula? In this respect we have hardly any empirical evidence that may guide such decisions.
To give an example, many people advocate the introduction of technology as a separate school subject as a necessary requirement to prepare pupils adequately for an evermore technological future. However, would it really be the case that British pupils will be better equipped for their future than Dutch pupils, because they will be taught about technology that way, while Dutch pupils probably won't? In fact, we have no clear guidelines to connect educational philosophy to practical educational decision making. As a result, the latter seems to be primarily a matter of taste, lobbying of pressure groups and political bargaining.

What role should we, science and technology educators, play or are we playing in such debates? Of course, that will differ very much from country to country, but it's my impression, e.g., from the problems with the British national curriculum, that quite often we are hardly leading such decision making processes, but rather following them, which means filling the slots that have been as-signed to us with syllabus content and teaching procedures. More systematic in-depth cross-national science curriculum studies and exchange of innovation experiences may possibly lead to more powerful insights and argumentations in this respect.

3. New contents?
That brings me to the second type of innovations. At the level of science curriculum content, even more aspects ask for consideration. The rapid development of science and technology asks for an almost continuous updating of the content of what has to be taught as the gap between school knowledge and science is becoming larger and larger. Should we teach at school about quantum physics and chaos? What to do with astronomy and cosmology, or computer science? Should neural networks, self-organising systems, modern biochemistry and views on genetics and evolution soon enter the school syllabuses? Or, should we better include much more technological knowledge, such as bio-technology, micro-electronics, or materials science, to name just a few from a whole spectrum? Or, shouldn't we focus that much on teaching theoretical conceptual knowledge, and shift our attention to scientific and

technological processes? E.g., by focusing on more open investigations, or design and construction tasks?

The above list is certainly not exhaustive, but it shows clearly a very old and basic problem, i.e., the ever increasing number of topics that have to be included in science and/or technology education. The regular way to deal with these demands is that every time a curriculum revision is at hand, a new layer of concepts and skills is added to an already full programme. However, as the conceptual structure of science is considered to be largely hierarchical, new concepts may be added but hardly any are skipped. This problem seems to be unsolvable, as long as we keep on holding the structure of the scientific disciplines, as a starting point for curriculum choice and design. Then, principles like 'scientific and technological literacy', or 'science and technology for all' do not solve it either, but only seem to make it worse, as the number of topics to be understood or to be literate about is almost unbounded.

In order to be able to meet all the justified demands to science education, a new way of thinking about the science curriculum structure seems to be necessary, that still has to be developed (see e.g., De Vos and Verdonk, 1991; De Vos et al., 1992). In some way it should start from the personal and social world pupils will live in, while, at the same time, rethinking the objectives, conceptual structure and depth of what is traditionally taught in science. However, leaving aside the relatively safe beacon of the 'structure of the discipline', does not make curriculum design much easier. On the contrary, I would say! For, as yet, we have no replacing comparably powerful guiding principle available.

A solution to this problem of 'elephantiasis of the school curriculum' (Kerber, 1988), proposed by many educationalists and often taken over by policy-makers (see, e.g., Frequent, 1994), is to emphasize the importance of general skills instead of specific knowledge. In line with the present proper emphasis on meta-cognition (see, e.g., White and Mitchell, 1994), it is advocated that schools should provide pupils with information processing skills, theoretical and practical problem solving skills and learning and study skills. The underlying belief is that the ever growing amount of specific knowledge itself is not that important, as, anyhow, much of it will become obsolete rather fast. Therefore, pupils should learn the skills to acquire knowledge, as a necessary preparation for lifelong learning.

Though I wholly agree with the value of focusing on such skills, to my opinion, this is no solution. In the first place, I fail to see what substantial part of the regularly taught science knowledge will really become obsolete. And in the second, I think that, as yet, there is little support from research that such cognitive skills can really be taught and learned as general skills, i.e., in such a way that they easily lead to the supposed transfer. On the contrary, I would say, from the present rise of 'situated cognition' (Hennessy, 1993).

So, though there may be a difference between cognitive and meta-cognitive activities in this respect, and though there is evidence that the adoption of 'good learning behaviours' can be stimulated (Baird and Northfield, 1992), to my opinion, it is still unclear to what extent this really may lead to justification of the 'less is more'- credo as far as curriculum choices are concerned.

Returning to science teaching, in the recent past, the demand for 'science for all' has lead to its contextualisation, i.e., towards more applications and real life situations. Attention for consumer science and citizen's science, apart from scientist's science has been a way to work this out. This STS perspective, which lay at the roots of IOSTE, becomes the most visible in attention to science related social issues. It unavoidably leads to the inclusion of still another type of activity, i.e., attention for ethical questions and decision making skills, as well as to reflection on the nature of science. Nowadays, the development of multicultural, anti-sexist and anti-racist science education should be added to this list. Thus representing another group of demands that we have to face.
As you may know, Dutch physics (PLON) and environmental education (NME-VO) curriculum development projects have played a leading role in contextualizing science teaching (Eijkelhof and Kortland, 1988; Lijnse et al., 1990; Eijkelhof and Lijnse, 1992; Kortland, 1992). Though these projects ended already some years ago, it may still be appropriate to say somewhat more about our experiences in this respect.
These projects have made quite an effort in developing a particular type of STS curricula at the secondary level; their rationale can be briefly characterized as 'teaching science actively in everyday and issue-related contexts'. From such teaching, it was expected, on the one hand, that pupils would experience the content taught as more relevant. On the other, that they would be better able to understand and connect the concepts and skills learned to their out-of-school world. However, how realistic were these expectations?
Before I report some research results, I should first say that the PLON-curriculum is in the first place a physics curriculum. STS-aspects were integrated with teaching 'real' physics. This caused a kind of unclear duality in the curriculum construction and in its implementation. For teachers, however, the matter is clear, pupils have to be able to pass the regular final physics-examination. That means that in case of doubt or of time constraints, STS aspects are skipped first.
In the case of the environmental education (NME-VO) project, the situation was almost the reverse. At first, it seemed as though the NME-units could be designed completely from their particular STS perspective, but now the problem was that environmental education is not a recognized school subject. Therefore the compromise of inclusion in several well established school subjects had to be chosen, which of course causes quite other problems of coordination between subjects and teachers.

Extensive evaluation of parts of the PLON-curriculum (Wierstra,1990) has shown that in general pupils did indeed experience the PLON curriculum as more related to their lifeworld and consequently as more relevant and motivating than

traditional curricula. This is an important outcome, even though the difference was less than hoped for and expected. The most positive was the fact that pupils appeared to like the active classroom climate that is typical for PLON-lessons. However, for both factors, named as reality and participation centredness, the personal influence of the teacher seems to be at least as important as that of curriculum content (Brekelmans, 1989).
On the other hand, the cognitive learning outcomes of the PLON-curriculum, in general, were not significantly different from those of traditional curricula. This unexpected outcome provided a reason for further reflection and in depth follow-up studies.

Our experience with a unit on 'Ionizing Radiation' (PLON, 1984; Eijkelhof, 1990) for senior-highschool (higher ability) pupils may serve as an illustration. Teaching about ionizing radiation and radioactivity in the context of risk and risk perception can be regarded as a prototypical example of STS teaching. A summative evaluation showed that though pupils valued the topic relatively well (particularly girls), cognitive learning results were disappointing. In particular, students were not inclined to use taught knowledge in their reasoning about situations for which they already had an opinion, such as: disposal of nuclear waste, nuclear energy, having an X-ray, etc.. At the same time, in their common sense reasoning about familiar situations pupils appeared to use a number of 'lay-ideas' about radioactivity, which seemed to be in conflict with the knowledge taught.
Both aspects could indicate that using taught knowledge of science in everyday situations is much less self-evident than often expected. It seems to ask for a transfer step that is usually not made if pupils have already familiar and satisfactory common-sense explanations available. This conclusion is endorsed by our work (Van Genderen, 1989) on the learning of mechanics in a unit on "Traffic", and of research on the learning of energy in the context of the problem of energy supply (Van der Valk, 1992). Kortland (1993; 1994), in his work on "Waste", showed that for younger pupils the aim of using taught knowledge in a rational decision making process is very difficult to achieve. This difficulty is not only related to the knowledge to be used, but particularly also to the question of what constitutes a rational way of taking decisions. From their point of view, pupils often see, e.g., no need to use extensive comparisons of disadvantages and advantages to come to a decision. I think, in fact, that we are dealing with the same problem in three different disguises. In the learning of concepts, in using concepts in the formation of an opinion, and in weighing opinions in the process of decision making, we encounter the problem that for many situations pupils use common sense concepts to express common sense opinions, possibly in a common sense process of decision making. The need to extend such common sense patterns of reasoning to more scientific patterns is for pupils not at all self-evident. And often rightly so, as it is mostly not the situations themselves that ask for such an extension, but the fact that they have been chosen by curriculum developers to figure as contexts for scientific knowledge. Therefore, a further reflection on the teaching strategy used in most curricula of the past, particularly also in those using a contextualising STS-approach,

including the projects described above, appears to be necessary.

In general one could say that in a traditional 'structure-of-the-discipline' type of curriculum, the concepts to be taught are the basic concepts of science. The sequence in which they are taught reflects its basic 'logical' structure. The situations in which these concepts are to be used are the usual idealized 'scientific' situations. It is precisely this latter aspect that many contextualising STS-curricula want to change by adding real life situations in some way, leaving, however, the conceptual structure and sequencing essentially unchanged. Apart from the fact that, because of the complexity of real situations, some new concepts may have to be added (see e.g., De Jong et al.,1990; PLON-vereniging, 1992).
I characterise such a teaching strategy as 'top-down', i.e., both in traditional and in many STS-curricula, teaching starts from and focuses on the perspective of science. Essentially, it is aimed at a 'top-down' transmission of concepts, even though the way in which that is done, may include lots of discussion and discovery activities. Such teaching almost unavoidably results in a process of 'forced' concept development, which may explain the apparent lack of differences in cognitive conceptual learning outcomes mentioned before.

I think that we therefore may conclude that most curriculum development of the past and possibly also of the present may have succeeded or may succeed in aiming at new objectives, but not yet sufficiently in an improved quality of learning. So, though much important innovative work on STS curricula has been done, there is still a need for essential improvement.

4. New ways of teaching?
This brings me of course to the third category of innovations, those directly related to research on teaching and learning science. To my opinion, much research in this field has shown that as far as conceptual learning is concerned, we are facing a major problem. It is now well known that pupils may have 'alternative frameworks' that should be taken into account, asking for, as it is argued, conceptual change instead of conceptual transmission (though there is still much debate about what conceptual change actually may mean). For all kinds of concepts, for pupils' and teachers' views of teaching and learning and for their epistemologies, so called alternative ideas have been described. Ideas that often have their origin in common sense thinking about the world, or result from teaching that does not deal with that appropriately.
For teaching in contexts, such common sense ideas play an even more unavoidable role than in traditional teaching. Pupils not only appear to have common sense ideas related to the concepts to be taught, that can certainly not be avoided while dealing with real life contexts from which they stem, but also opinions and knowledge related to these contexts themselves. As well as common sense ways of reasoning about and of decision making in such contexts. It is this latter type of pre-knowledge that explains why, even if we would

succeed reasonably well in teaching correct conceptual knowledge, it may still not be used in real life situations, as I have described. It would not result in an integration of science concepts with ways of reasoning in and about contexts, but in science concepts as something that is added on.

As you will know, a lot of research is done to find better teaching approaches. Most of it is done from a so called 'constructivist' perspective, which is reflected in statements like 'meaning is constructed' and 'concepts cannot be transferred from teachers to pupils' (Duit, Goldberg & Niedderer, 1992), etc.. As such, educationally, this is an important non-trivial change of perspective (even though it is called trivial from a philosophical point of view). However, on the other hand, adopting a 'constructivist' perspective does not say yet very much about how to teach. The phrase 'the teacher must have a good idea of what concepts the students might already have and then engage students in activities that would help them construct the desired understanding' (Duit e.a, 1992), may easily be interpreted in an insufficient way, as we will argue now.
The late Dutch mathematics educator Freudenthal (1991), in a comment on 'constructivism', writes as follows: "If I were to accept the term 'constructivism', I would mean a programme having a philosophy that grants learners the freedom of their own activity."
He points, in my opinion, to a basic problem. When this freedom of learners is ignored, teaching unavoidably results in 'forced' concept development and thus very probably in misconceptions. It is almost a contradiction to adopt 'constructivism', i.e. the view that pupils construct their own meaning based on what they already know, and at the same time either to prescribe what they have to construct or to immediately devaluate what has been constructed (as is done in the status-changing model of conceptual change). The basic problem for constructivist teaching thus is how to design teaching such that it guides students to construct in freedom the very ideas that one wants to teach. In most 'constructivist models of teaching' sofar worked out, it is precisely this necessary freedom of learners to make and follow their own constructions that is either lacking or being underestimated. In fact, one could then cast reasonable doubt on whether such approaches should be called 'constructivist' at all.
From a curriculum point of view, most 'constructivist' approaches, published sofar, may best be characterized as using new strategies to improve top-down teaching. Pupils' ideas about certain 'difficult concepts' are taken into account 'constructivistically', but within a traditionally structured teaching sequence.

Probably, a more radical change is needed. The aims of STS ask that pupils are able to use scientific knowledge in their reasoning about out-of-school contexts, or even to reflect on the nature and social value of such knowledge. In view of the above, one cannot but conclude that such aims seem to be rather pretentious. Anyhow, a certainly necessary prerequisite seems to be that pupils really understand what they are taught and be able to constantly integrate it in their 'living use of language' (Klaassen, 1994). This probably asks for a 'bottom-up' teaching process. We could say, I think, that we should not teach the

concepts of science (as a product), not even in real life contexts and/or in an above mentioned 'constructivist way', but guide pupils in the activity of 'scientificalising' their world. Insightful learning can only start where pupils are, which asks for understanding the concepts, basic ways of reasoning and language they use and motivations they have. Teaching should be carefully designed such that students can build positively on and extend what they already know, in relation to contexts that are or are made meaningful to them. Only then may we expect that knowledge, language, opinions and actions remain integrated, as particularly STS seems to ask.

Of course, all this is not particularly new. Nevertheless, as yet, we have no general rules for the design of such teaching, apart maybe from the fact that we are always inclined to overestimate our own intuitive expertise. It asks, I think, necessarily for an empirical process of closely interconnected classroom research and development, which we call 'developmental research' (Lijnse, 1994). A careful process of small scale curriculum development, cyclically coupled to research of teaching/learning processes of a particular topic. Thus resulting in a careful and transferable description of 'good teaching practice'. At present, the amount of content specific research aimed at 'constructivist ways of teaching' is increasing, but, to my opinion, research in our field is still too much aimed at developing general theory and strategies. At contributing to psychological theories and philosophical discussions about constructivism's, 'mental modelling' or 'understanding the mind', and thus resulting in implications for teaching only. However, to change practice, such theories and implications are of limited value, as past experience has shown. Though, of course, theoretical understanding is useful and necessary, it leads almost unavoidably to a theory-practice gap (Wright, 1993). A gap that cannot be bridged by application of general theory, but only by additional content specific research aimed at developing understandable teaching and learnable curriculum structures. A type of research that still largely has to be developed. International cooperation in a programme of such 'developmental research' could probably result in the so badly needed real progress in our field.

5. Summary and Conclusion

So let me summarize and come to a conclusion. I've described that science and technology educators, as well as educationalists and policy makers are advocating a large number of new goals. So many, in fact, that they cause science education to be under heavy pressure of constant change.

At the same time, research on teaching and learning has shown that we do not even succeed in reaching our traditional goals. I'm afraid that many curriculum innovations, whether they aim at new conceptual areas, or at decision making, at process skills, at the nature of science or at technology, in fact, mainly lead to the same evil. Apart from 'forced' learning of ever more concepts, now also 'forced' learning of, e.g., skills or views about the nature of science has to take place.

I think, we therefore have to be very modest. Science educators like to change the world, but in fact they do not sufficiently know how to teach the most basic concepts like force, energy, or chemical reaction so that in general pupils like it and really understand it. It could well be that if we would have learned to succeed in doing so, we would also have solved most motivational problems, for which now the innovations are advocated that cause the very pressure that will certainly prevent such understanding. Then science will probably have lost its image of incomprehensibility and irrelevancy.
In our experience, educational policy makers focus completely on advocating new goals and subjects, having little or no attention for underlying teaching and learning problems. Therefore they have a much too simplified view of solving problems in education. In fact one could say that they seem to have no view for quality of teaching at the classroom level.
Traditional curriculum development has shown itself to be inadequate from the point of view of improving learning and teaching. It should be supplemented and/or replaced by an empirical process of developmental research.

My previous categories clearly reflect a way of top down thinking about educational innovations. Large scale thinking about developments in society and in science and technology determine what has to change in education. If we do not succeed in countering this top down philosophy, in finding a balance between this kind of thinking, and letting innovations be determined as well by what appears to be understandably teachable from bottom up research on learning and teaching science, a lot may change but we will make no educational progress. I wish you much success in setting some further steps in this direction at this conference.

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Co-report

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I should say that, unlike Piet, I am an optimist - but many of my colleagues call me a naive optimist. That may be something you want to comment on later. I want to briefly react to Piet's lecture by considering what I see as the essentials of his arguments, to reinforce these by giving some alternative examples, and, in one instance, to mildly disagree. I will do this by considering the three categories that Piet used to discuss educational innovations.

The first of these categories was innovations involving introduction of new subjects.
My prejudice is to believe that the significant issue here is, to paraphrase Piet, "decisions about new subjects are rarely, if ever, based on the results of research on classroom learning". One very significant factor in this is that the decisions about new subjects are invariably made by people who at best *used* to teach in schools, and at worst (and often) have never taught in schools.
I think there is a lot to be learned about teaching, and education more generally, through the consideration of relevant parallels with other professions. We in education very commonly consider our differences from other professions, even though the parallels would be helpful to us.
In this issue, for example, I see an interesting parallel with the profession of architecture. I would guess that around 90% of the people in this room have at some time or other said that architects should spend time living or working in what they design so as to eventually remove some of the design inadequacies *we* have to live or work in. The same issue exists for those in education who propose and develop new subjects in isolation from schools. Such people can have at best only inadequate understanding of the fundamental and complex intertwined issues, both practical and professional, that are involved in the school and the classroom. Too often these people have no understanding at all. To use another term introduced by Piet (or, perhaps, to misuse the term), such people have little or no situated cognition.

The second of Piet's categories: innovations involving new content. I want to comment on two issues raised by Piet in this section of his lecture. The first - we add new concepts and we don't remove any- is so true. I think there is something very interesting in what seems to me to be the only obvious exception to this. While obvious, it is a strange exception in some ways as it came very much out of the context of the structure of science. PSSC Physics is a really interesting exception to this general rule of content always being added and never removed.

With PSSC we had a new senior high school curriculum, emerging in the 1950's in the United States, which had no sound, no heat, almost no electricity. When PSSC was introduced to high schools in the state of Australia in which I work, university physicists believed that plague and pestilence would be upon us because the Wheatstone Bridge had been removed from the school curriculum. Of course there was no plague and no pestilence.
What is interesting about PSSC is that here is an example where there was a dramatic reduction in content. I think that the relevant issue in this is that PSSC had a rationale which was sufficiently specific as to enable one to make real and specific decisions about content. Most curriculum rationales are, in this sense of what content to include or exclude, so general as to be pointless in terms of deciding what content. Hence we find content added and not removed. Another example of this unhelpful generality in curriculum rationales came a couple of years ago when Peter Fensham and I, quite unknowingly, gave a terrible task to a research assistant. We set the research assistant to reading a large number of science curriculum documents and policy statements, substantially from Australia and New Zealand but also from elsewhere, in order to try to tease out what the consensus meaning in these documents was for quality. I have to tell you that we don't know what the consensus meaning was because none of these documents told us anything of what the writers of these documents meant by quality. The term was often used, but never explained in any form. So, here were curriculum rationales using words like quality in ways so broad as to be pointless. And that is the context in which curriculum rationales often exist; hence these do not give any direction for making content choice.

The second issue I want to raise from Piet's second category of innovations - those involving new content- is that of learning how to learn (or metacognition), and to again consider situated cognition. It is clear to me that there is considerable collaborative research with teachers in schools that shows that students can learn how to learn, and that the way to foster this learning is quite consistent with situated cognition. The one thing I think we know very well about metacognition is that you cannot teach these sorts of things in a decontextualized way.
You cannot teach students things about learning unless they are learning something.
Said in that way this may seem obvious, but it certainly is not obvious to many. The point I am wanting to make here is that the process of learning and the content being learned are intertwined, and you cannot teach a completely generalizable learning skill.
You can teach students about the processes of learning as they are learning, but only part of this will be generalizable to other learning contexts. Context is so important that nothing is ever going to be absolutely generalizable.

Piet's third category of innovations was those involving classroom teaching and learning. I want to comment here on constructivism, in particular on Piet's use of "top-down" in his consideration of constructivist teaching. Constructivism is an

interestingly difficult word these days because I often have no idea what other people mean by the word when they use it. It is common for writers/speakers to use the word without making clear the meaning they have for it. Personally I have to say that if I have desired learning goals for my students, if I have intended instructional endpoints that I seek to move my students towards by creating appropriate situations in my classroom, then I totally reject that this is a top-down approach. For me teaching from a constructivist perspective is learner centred and very strongly teacher controlled.
The messages from constructivism have to do with the nature of the control, with the need for the control to be based on and determined by considerations of *learning* rather than considerations of "covering the curriculum". The English physics educator John Lewis once said that when people talk about the difficulty they have in covering the curriculum they forget that it is learning that takes time, not teaching. In other words, it is easy to forget that the point of schooling is learning; teaching has point only when seen in terms of learning. This view suggests control of a subtle form, determined by considerations of student learning, is what I am advocating. Regardless of what happens to the research enterprises on which constructivism is based, it seems to me that the fundamental and obvious principles of what some people want to call naive constructivism -and I want to call sensible or pragmatic constructivism- will remain. If we use these appropriately they will tell us much about teaching that fosters good learning.

In summary then I do want to say that I agree wholeheartedly with Piet's conclusions, except to point to one example of content reduction and why this happened and to disagree with the view that there is some sort of inconsistent logic in the notion of classrooms based on constructivism. I want to end by stating the obvious. However, we want to consider the issues raised by Piet, the classroom teacher is central. And in many ways that's the beginning, the middle and the end of thinking about issues associated with innovations. I strongly believe that we need to accept the centrality of the classroom teacher and work with the positive consequences of that, and stop pretending that we can somehow find a way to ignore the classroom teacher.

STS-education: contents and teaching methods; assessment; teacher education - within claims & strategies

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Summary

Papers presented within this claims and strategies section of the Symposium contain a diversity of insights, experience and policy proposals from a wide international perspective. Interesting new curriculum developments are reported alongside teacher training strategies and assessment initiatives. Subsumed within these apparently disparate strands several general and important curriculum issues emerge. These principally focus on 1) the issue of separate or integrated development of science and technology education in a world increasingly dominated by the consequences of human endeavours in these fields; 2) the case for a radical restructuring of school curricula towards a more holistic approach designed to nurture citizens of a 'global village' faced by environmental crises and 3) the adverse influences upon school education on the one hand of existing assessment practices and on the other by traditional patterns of curricula and teaching in higher education.

Introduction

Science, technology and society education has a relatively short history and it exhibits many different interpretations according to local culture and educational framework. One unifying characteristic its international exponents share which was evident during the Symposium is commitment and enthusiasm which, in turn, ensures vitality of curriculum discussion and development. As a young subject STS is not constrained by parameters born of tradition and so, just as in previous IOSTE Symposia, debate about the balance of emphasis between science and technology and the facets of societal interaction formed a strong thread through the proceedings. Key facets of this balance surfaced frequently. First 'technology' has achieved new status in the curriculum in many countries in recent years. Participants with a technology specialism were strongly represented and although they tended to use the term 'technology' with rather different meanings, technology made strong claims for a pivotal place in the STS triumvirate. Advocates of environmental education pleaded their cause with similar cogency and it was argued that STS should give way to STE.

Another recurrent issue arose from the Symposium focus on the 'demands of society'. Some discussed the form STS education should take from the perspective of personal experience of a society in which the majority of young people today are illiterate and where education takes place in schools with a minimum of facilities. Others, by contrast, considered the kind of scientific and technological literacy appropriate for a consumer orientated, high-tech society yet where levels of unemployment demotivate those approaching school leaving age. Despite these starkly contrasting national circumstances, there was a measure of convergence due, on the one hand, to shared aims and, secondly, to some parallelism of trends in these very different national situations. Trends in vocational education was one such convergent strand which received attention.

There was much common ground attending the global aims of STS education in that it seeks to nurture human understanding of science and technology for peaceful and sustainable development. In this context it is pleasing that cross-national STS curriculum innovations were reported. Value dimensions of STS were passionately aired and profound issues about how far education should serve the immediate needs of society and how far it should aim to work for change in society began to be addressed.

Explicit attention was given to the fact that STS is an integrated study bringing together three broad facets of human experience and endeavour. Problems with both the status of integrated curricula and with the teaching demands of such curricula was acknowledged but in the context of strong affirmation of the benefits of integration for the learners. The dangers of repetition of content for pupils when integration is seriously attempted were not dismissed though of greater concern are trends apparent in some countries to re-emphasise specialist studies in separate subjects especially for more able pupils. Few of the papers precisely identified the target audience for STS but there was a general reluctance to see STS as a second class subject, to be side-stepped by those with the potential to be leading scientists and technologists of tomorrow.

On a more positive note new curriculum developments in STS revealed careful subject integration matched with attempts to incorporate appropriate learning strategies and accompanied by appropriate research and evaluation studies. Attention also focused on the demands upon teachers of STS education and experiences were shared about ways to help them develop the skills to evaluate issues and materials for effective and balanced presentation of STS topics in which the values dimension is responsibly treated.

The important influence of assessment on the emphasis teachers give to different topics and the significance of assessment data on the actions of policy makers was highlighted. The status given to STS content in the current Third International Mathematics and Science Study (TIMSS) was noted as a salutary reminder of the potential for assessment data to result in comparative performance tables which disguise the bias embedded in the assessment itself.

Indeed, caution about assessment data was further stressed as participants were challenged with respect to their understanding of the assessment of process skills as measured by conventional practical tasks.

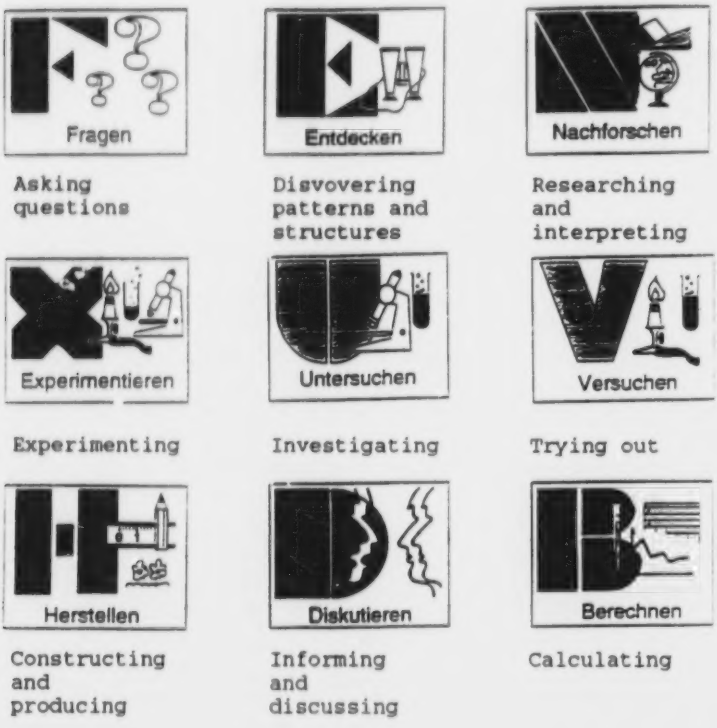
Issues and trends

1. Curriculum developments

'Practising Integration of Natural Sciences' (PING) is a science scheme begun in the state of Schleswig-Holstein in the Federal Republic of Germany for pupils in grades 5 and 6 but now continued into grades 7 to 9 and with the expectation that it will go to grade 10. Bunder's presentation (see Bunder & Lauterbach) excited interest as he outlined the characteristics of this programme and showed sample materials. PING is a conceptual framework for basic education in science. This conceptual framework, fully described in the paper, has been securely founded on theoretical principles. It is a framework which is potentially transferable to other situations and it clearly articulates the grounds for integration, for cooperative learning, for autonomous individual development and spells out that the basic educational content emphasises the relationship of humankind to nature. PING is not a closed and completed teaching-learning programme but an open, developmental research project in which, it is claimed, theory and practice mutually interact. PING is more than a constructive attempt to bring separate sciences together and has an explicit STS bias as its first educational principle reveals: 'Science education takes place solely in an experienced, reflected and arranged relationship of humankind to nature, to one's fellowman, to culture and to one's self.' A glance at course materials immediately shows how these principles are applied and learners are assisted by a set of logos to appreciate exactly what learning method each activity involves, figure 1 (page 64). As a piece of curriculum development upon which development and research is continuing readers are advised to await further reports with anticipation.

Another example of research related to curriculum development featured the Dutch national science curriculum and especially the place given to seven cross-curricular themes (CCTs) in primary and lower secondary education. In his paper Boersma discusses the importance for pupils of continuity of learning and of the difficulties of achieving this across the primary/secondary interface especially with respect to CCTs which often demand a multidisciplinary approach to complex social problems. Example of CCTs in the Dutch scheme are drugs, the consumer, traffic and the environment. While the detail is specific to the Netherlands the general issues are familiar in many countries. He reports on analyses which show how the CCT's are embedded in attainment targets for different subjects. He identifies as a discontinuity any instance where there is either no link 1) between attainment targets for different subjects within primary or lower secondary education - lateral link or 2) between attainment targets for primary and lower secondary education - longitudinal link and 3) where considerable overlap occurs.

Figure 1: PING logos to stimulate student awareness of methods for knowledge development



The discussion then centres on means to resolve these discontinuities so as to achieve better continuity for pupils in the learning process. Practical long term solutions are considered relating to curriculum revision as well as immediate, ameliorating steps within the scope of individual teachers. Most significantly Boersma concludes with the observation that it is important for pupils to be helped to take responsibility for their learning process for it is within the individual that synthesis into a personal cognitive structure takes place. This personal responsibility of the individual for learning, already noted with respect to PING and advocated by keynote speakers, thus became a much underlined criterion of particular importance with respect to multidisciplinary complex issues.

McGrath's paper reviews the scope and impact on science teaching of the range of STS materials developed in England by the Association for Science Education (ASE) under the generic title SATIS (Science & Technology in Society). This highly regarded project already has a ten year history but belongs to that STS genre in which science is the leading partner and the materials are designed to

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supplement traditional science teaching; this is the approach Fensham calls the cautious approach to STS (Fensham 1991) Interestingly McGrath reports a new initiative, Science with Technology (SwT), a joint enterprise between the ASE and the Design and Technology Association (DATA). Unfortunately McGrath did not comment on the collaborative venture between a number of European schools in using some specially selected SATIS materials because this would have complemented the paper presented by Zylbersztajn in which he reports on a co-operative link between two higher education institutions, one in Brazil and the other in England (Zylbersztajn & Watts). Their co-operation has developed and trialled teaching materials within STS using an approach they call event-centred learning. The characteristics of this approach are the exploration of 'real life' events which are well documented through books and media resources so as to engage students, some of whom are trainee teachers, in relevant problem solving. Students present their solutions through role play, drama and television presentations. Necessarily the events chosen for this work need to be equally relevant in both countries and the two topics trialled are reported in some detail. This collaborative activity has a research dimension and the paper describes the favourable response of participating students but also identifies numerous questions for resolution and further study. The application of modern technologies to promote learning across national frontiers is entirely consistent with the aims of STS and its growth is to be encouraged.

2. STS an evolving study

The status of the T in STS inevitably received renewed attention. It is worth recalling that Hofstein et al (1988) reporting on discussions at the Fourth IOSTE Symposium were able to say 'STS was generally understood...to mean teaching science content in the authentic context of its technological and social milieu. Students tend to integrate their personal understanding of the natural world (science content) with both the man-made world (technology) and the social world of students' day-to-day experience (society).' This prescription of STS would not match the tenor of either papers or discussions at the 7th Symposium. Since 1988 technology has gained new curriculum importance and impetus in many countries and the aim articulated by Layton (1988) that technology should have an equal status with science was echoed and extended during these proceedings.

Significantly Clarkson referred to technology education as a discipline, while admitting that 'technology is a concept with no simple agreed meaning'. He cites numerous definitions of technology and adds his own analysis of technology by identifying three key characteristics, namely artefacts, human beings and theoretical and technical knowledge. In essence Clarkson's educational view of technology is close to that of the UNESCO definition of 1983 and which still has usefulness:

'technology is the know-how and creative process that may utilise tools, resources and systems, to solve problems, to enhance control over the natural and man-made environment in an endeavour to improve the human condition.'

Clarkson is concerned to suggest how technology education can help society to maintain the benefits of technology while minimising its disadvantages. The curriculum model he proposes aims to 'provide pupils with an instrumental and a critical understanding of technology to prepare them for life in a technological world'.

Christine and Edward Ebert (Paper a) define technology more broadly as 'that field of study which seeks to combine specific elements of information in order to develop products or processes which enhance, or extend, one's capabilities.' This definition certainly does not imply subordinance to science but their view is elaborated by two simple statements suggestive of a relationship. 'Scientists focus their efforts on increased understanding of the world around us. Technologists make that knowledge valuable in a practical sense.' Needless to say, this uni-directional interaction was challenged. Nevertheless, the Eberts shared with Clarkson a desire to utilise technology education to go beyond the instrumental function towards the development of a social conscience. Their particular focus is on ethical dilemmas which arise through technological innovations and which can be presented to students through creative problem-solving case studies.

The Clarkson and Ebert papers share much in common and concentrate on technology and society but almost as an endpiece the Eberts argue against curriculum fragmentation. It is their view that an integrated approach will help students to appreciate both the subject interaction and total context of many of today's relevant and pressing social issues. They go further and specifically advance environmental education as an ideal vehicle for effective delivery of science, technology and social studies education which can readily emphasise problem solving and decision making. It is at this point that support came from Gilbert and Dillon whose paper argues the case for STS to be approached in a multi-disciplinary way and suggests a unifying framework in which greater emphasis is given to the environment and the many social, economic and political issues that relate to it. Thus they propose the replacement of STS by STE.

Kahn brought a different political perspective to these issues as he contemplates the most beneficial relationship for science and technology in the new South Africa. In this country technology has only recently emerged as a school subject where its declared aim is to create technological literacy, to enable learners to 'lead meaningful lives' and to respond to employment needs though, Kahn notes, there is a silence on values. The new government policy guidelines indicate a desire to move science education away from an excessive factual and academic position by a proposed 'technologization' of science in which technology becomes embedded in science so that the gap between pure and applied science

disappears. Through problem-solving, design and construction of artefacts based on scientific principles 'academic' science and 'vocational' technology will, it is intended, be harmonised into a 'Science for all'. Kahn supports the science and technology approach for his country at this particular time, not least because there is no cadre of teachers who could be labelled 'technology teachers'. He observes that, despite their limited qualifications, there is a science teaching community on which to build but in order for this development to take off he identifies in-service needs and calls for revision of initial teacher training.

Williams, with reference to Australia, presents a different pattern of interplay between science and technology. He refers to the Australian Education Council (AEC) national subject 'statements' and 'profiles'. 'Statements' outline essential learning that should be included in school curricula and 'profiles' define what students can know and do over time so that they describe progression and provide a framework for reporting student achievement. The science statement he considers has its prime focus on equipping the young with an appreciation and understanding of science. It does not have a vocational focus and he cites critics of the policy who consider it too socially orientated and argue that it continues into secondary school an approach designed for primary education. Similarly he indicates that the technology statement is avocational in its emphasis on technology for all. While recognising that education which assists making informed decisions about both the development and impact of technology is vital, William's observes that in a world in which technology changes rapidly, the skills most important for education to develop are flexibility and adaptability.

Williams concludes that though science and technology syllabuses continue to be independent there are parallel trends emerging. Both currently move away from a vocational approach, both seek to embrace a greater process emphasis at the expense of content but teachers and students, he suggests, have found this difficult. Both include environmental and other socially related factors and this faces schools with a reorientation from a largely academic bias. It is, says Williams, the move away from a vocational approach that blurs the distinction between the two subjects, for, in a general syllabus high in relevance to students, the two subjects become more interdependent. Consequently he believes a general state of confusion about the difference between science and technology will continue!

Although contributing from a Canadian perspective Crawford lifted the discussion of subject balance and curriculum integration to a much more general and theoretical level. His paper argues a strong case for 'holistic education' on a world wide scale in order to confront the catastrophic consequences of the continued misuse of natural resources by peoples across the globe. Unashamedly Crawford asserts that 'the basic dilemma of the world is moral, ethical and spiritual'. His paper draws upon numerous sources to support his case. 'Holistic education', he says, 'means education of the whole person in a person-planet world' and therefore a key emphasis is interconnectedness. Such education

would help students to develop a forward looking disposition in which there would be a commitment to 'personal, social and environmental responsibility; a respect for diversity within an acceptance of commonality; a concern for justice, equality and peace; an expression of solidarity with peoples across the globe and a recognition that acting morally is acting in a way future generations would ask us to act'.
His paper discusses a number of schemes for designing general education curricula to meet these holistic goals and his oral presentation added substantial further material, a sample of which is included in Table 1 and Figure 2.

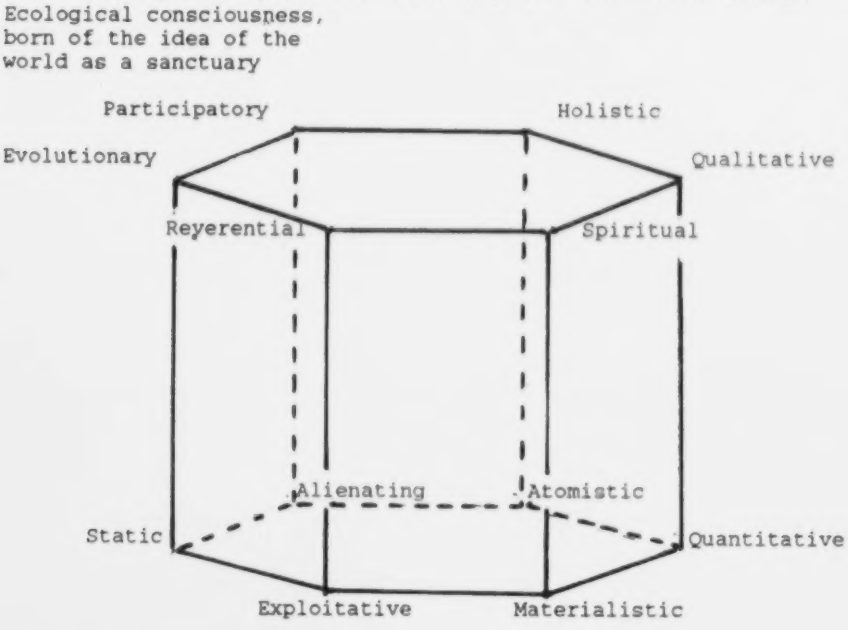
Table 1. A selection of key features from a checklist of two world views (after Greig, Pike and Selby 1989)

The Fragmentationalist Worldview	The Holistic Worldview
An emphasis on separateness and disconnectedness. Wholes are made up of parts; the whole is no more nor less than the sum of the parts. We are separate from other peoples and the global environment.	An emphasis on connectedness. Parts are only finally understandable if viewed in dynamic relationship with all other parts. The combined interaction of all the parts creates an organic whole which is greater than the sum of their individual effects. We are profoundly connected to other peoples and the global environment.
A preference for analysis and reduction.	A preference for synthesis, integration, the synoptic.
The observer is separate from what she observes; complete objectivity is achievable.	Observer and observed are intimately connected. What is observed, how it is observed and resulting interpretations are influenced by the observer's priorities, values and framework of thought. The observer is to some degree observing herself; she is neither 'outside', 'neutral' or 'objective'.
The rational and cerebral are separate from and superior to the emotional, the intuitive, the spiritual.	Our full potential is only realised through the dynamic and equal interplay of the rational and cerebral with the emotional, the intuitive and spiritual.

Many STS adherents will value his collation of evidence in support of integrated studies and find sympathy with the holistic worldview compared with the fragmentationalist worldview quoted from Greig, Pike and Selby (1989), see table 1. Crawford also drew upon the philosophical work of Skolimowski (1992) whose categories of ecological and mechanistic consciousness have some resonance with the thinking of Greig et al. The model of consciousness suggested by Skolimowski, figure 2, could serve as a tool for teachers to evaluate the key features and attitudinal dimensions of their existing curricula.

Crawford's paper then embarks on the case for technology to be made a central theme within holistic education. His approach to technological education and technological literacy repeats much included in other papers, especially that of Clarkson.

Figure 2: A model to represent both mechanistic and ecological consciousness in a dynamic, open-ended relationship, after Skolimowski (1992).



Perhaps it was a pity that he did not rest his case with the 'holistic curriculum' argument because this paper opens up the most far reaching possibilities. However the amount of material presented and a strictly timed programme prohibited sufficient formal discussion.

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3 Manifestations of a demanding society

It will already be apparent that papers dealing with interface issues of science/technology and society were based on both local contexts and real world concerns. The demands upon education in the new South Africa were explicit in Kahn's paper as were new political strategies to address the situation. Other papers specifically focused on the nature and manifestations of demands made by society.

Since STS exponents are generally concerned to raise democratic responsibility of the community it was pertinent that Panwar described the attempt to achieve consensus on school programmes through consultation with all stakeholders prior to the development and introduction of new school science programmes. His exposition of the impact of these consultations on science programmes confirms wide support for the integration of separate sciences with a social dimension. It also exposes the continuing resistance from an important sector of the community to this broad, integrated approach for pupils of high academic potential. Experience of the national curriculum in England has similarly confirmed a desire to perpetuate separate sciences in the final two years of compulsory schooling, with these concerns coming most strongly from the independent sector and selective schools. Jennings, from the context of the centrally controlled curriculum introduced in England in 1989, especially identified the role of parents and of the scientific community in articulating demands which science education is expected to achieve. However, he suggests that science educators themselves through their ambitious curriculum plans and goals have contributed substantially to these public expectations. Now, several years after the new curriculum innovation, science teachers have voiced their objections to an overloaded and assessment led curriculum. Simultaneously, inspection reports and test data reveal that pupil achievements scarcely fulfil society's expectations. Jennings concludes that, for the future, science educators need to base their curriculum plans on better researched foundations rather than upon laudable aspirations otherwise they may find that curriculum decisions have been appropriated entirely by political policy makers.

While these two papers focus on particular 'stakeholders' through whom local and national 'demands' are evidenced Dreyfus raises the issue of society's demands upon education in a more general context. He recognises the reality of society as the fast changing 'market place', an existing order that schools influence but little and into which its students emerge and have to compete. Dreyfus is even more concerned about the demand of society as 'mankind in search of sustainability' and here he is on common ground with many presenters. He is equally exercised by the demands of a 'civilisation in search of values' and in this respect approaches Crawford's position. His objective is for education to be a catalyst to a new social order and asks 'will things ever change if we do not educate a generation of potential changers, who possess the necessary cognitive abilities, attitudes and knowledge? His advocacy of a well articulated form of

scientific literacy as a contribution to the formation of a cohort of society 'changers' reveals his personal scientific background but others equally clearly spelt out the technological side of the coin. Again, Symposium time did not allow for exploration in depth of the broad issues that Dreyfus presents but it is to be hoped that his paper will sow seeds in fertile soil.

4 Teacher education

The topic of educating teachers for the demands of STS teaching surfaced frequently during the proceedings. Christine Ebert spoke from her experience of training elementary teachers as she described how she uses a historical perspective to help them demystify modern technologies. Borrowing an idea from the two-faced Roman god Janus who was capable of seeing in opposite directions (the Janus perspective) her paper explains, with carefully selected examples, how looking back to earlier ways of doing things can be utilised to help solve contemporary problems. The Ebert's paper (Paper b) asserts that the rapid growth of sophisticated technologies has resulted in a serious lack of personal understanding of technology. The thesis of their paper is that both student teachers and children can be assisted to apply a historical perspective to the valuable activity of discovery inventing and by this means are helped to bridge the conceptual gap between the 'visible' methods/technologies of yesterday and the 'black box' technologies of today.

Daugs' contribution adds another strategy for helping both trainee teachers and those on in-service programmes to gain confidence in dealing with value-laden STS issues. Indeed Daugs' approach goes beyond building personal confidence in its concern with the 'mix of knowledge and feelings that contribute to a person's attitude level of science, technology and social literacy' His programme is designed to 'structure student experience so that they are empowered to solve problems' and on the way to articulate for themselves a personal philosophy which is tested in the context of co-operative learning groups.

His approach is immediately attractive in that it utilises free or inexpensive curriculum materials available from industries, government agencies and special interest groups. The method involves evaluation of these materials from a number of perspectives but, it should be noted, the Daugs' approach is rigorous and time consuming. It includes study and practical investigation to secure content background of the scientific/technological knowledge and similarly for the social knowledge element which may include economic, ethical, legal, political, emotional and aesthetic components. Furthermore each student is required to verbalise a personal philosophy pertinent to the issues under study. Thus the task may be to write a personal environmental ethic. Only after these foundations have been established students proceed to make informed decisions and proposals of the kind which are central to STS problem solving. Within his paper Daugs presents details of his strategy and with it an STS problem solving model

that will repay study and which should transfer comfortably into other national cultures.

5 Assessment

Three papers were concerned with assessment issues. Tamir offers a number of flexible and interesting modes for the assessment of STS and in so doing effectively endorses a point made by Fensham that assessment of STS cannot be done adequately by items capable of response within one minute. Fensham gives valuable insights into the Third International Mathematics and Science Study (TIMSS) by identifying ways in which STS fits into the assessment framework. His paper makes cautionary reading because he shows how the TIMSS framework appears to take proper cognisance of STS developments, but then he reveals how the constraints of the assessment programme effectively mean that there is little opportunity for adequate testing of the conceptual learning of the kind with which STS teaching is principally concerned. Fensham is anxious about the comparative league tables which the TIMSS data will generate and the potential impact of these test results on science education policies and science curricula for pupils in schools at the turn of the century. The message of his paper is to urge science educators to understand and appreciate the nature of this assessment exercise in order to ensure that politicians, teachers and the general public are helped to interpret the results. This exercise will, he suggests, be essential where STS features strongly in the national science scheme because TIMSS will discriminate against this approach when compared with a traditional science fact dominated curriculum.

Caution about interpretation of assessment data is also the theme of Erickson's paper, but his reservations stem from research studies and are not specifically STS related. He asks the pertinent question 'What are science performance (practical) tasks assessing?' In a carefully argued presentation, supported by results obtained from a study of performance tasks included in the 1991 British Columbia Science Assessment, Erickson concludes that their performance tasks were not in fact assessing a well defined and discrete set of process skills. Comparative results of students in grades 4, 7 and 10 who performed the same tasks did not yield the progressive pattern anticipated and, says Erickson, we 'do not have the nice, clean learning dimensions and abilities articulated in our assessment framework'. He concludes from his evidence that it 'will be extremely difficult... to develop tasks that will assess discrete, science process skills that are independent of the content domain in which they are located' and he adds that he seriously questions whether we should even continue to use the 'language of 'process skills' that are unique to science'. Significantly he continues, 'This preliminary analysis and the related conjectures regarding the interactions between the different types of student knowledge and the importance of the different ways that students might frame instructional or assessment settings, would suggest that our responsibility as educators is even

more complex than I had originally considered it to be'. Erickson's detailed discourse which reveals the need for subtle interpretation of the results obtained from a carefully structured local study, serves to lend weight to Fensham's admonition to treat the results of the fifty nation third international assessment study with extreme caution.

Discussion and conclusions

While it was altogether predictable that the Symposium would see the continuance of discussions about the interplay between the inter-related elements of science, technology and society it was disappointing that so much time was given to particular STS formulations at the expense of fundamental debate about the integration issues involved. The science and technology interface has been explored in depth by Layton, (1988, 1991) whose plea for a balanced partnership has already been noted and Gilbert (1992) who described the relationship between school science education and technology education as 'fairly uncharted waters'. The proceedings reported here do little to draw a chart but go some way to endorse the less optimistic diagnosis made by Fensham (1991) at the 6th IOSTE Symposium in which he highlighted the gulf between science persons, *Homo sapiens* (to use Layton's terminology) whose preoccupation is with knowing and technological *Homo fabre*, the making persons. Therefore while time constraints may account for some lack of engagement with critical integration issues it is probable that the gap between the culture of science and that of technology is itself an obstacle to constructive dialogue.

Of the three different scenarios for curricula in science and technology tabled during the proceedings, two will certainly have tangible expression in different localities. Khan, whose paper shows his comprehension of Fensham's analysis, concludes on pragmatic grounds that an STS integration which embraces a science for all philosophy is right for South Africa at this stage in its history. Other examples of STS courses presented were often focused on primary and the early secondary years. Certainly with respect to highly developed countries there was much ambiguity as to whether these courses meet the educational needs for the most able and, if Jennings' analysis of the British scene is correct, then STS educators should be on their guard against projecting aims that have little chance of being translated into achievements.

Separate development of science and technology curricula was evident in other presentations. Williams' account elaborates separate curricula but with parallel moves to embrace a society dimension and a retreat from overt vocationalism. As Boersma and others have stressed integration of factors on complex issues always ultimately rests with the individual but nevertheless educators should seek to facilitate this process. Where separate science and technology curricula are developed the interface is bound to be messy; science education increasingly looks to technological developments to lend relevancy to content and much

technology depends upon scientific insights into the nature and properties of materials. Given that science and technology are growing at such a rapid rate it is plausible to argue that a combined, integrated curriculum is too unwieldy. If separate curriculum pathways are programmed as reported by Williams there seems to be merit in the adoption of the research strategy which Boersma outlines so that curriculum discontinuities across as well as within subjects are identified. In this way planning for continuity of learning may be attempted as a step towards helping individuals in their personal synthesis with respect to complex social issues.

Against the background of many papers which provided particular attempts to work out these curriculum tensions, one or two papers asked more fundamental questions. While Dreyfus argued the case for education that develops scientific literacy, the questions he asks about what it is that education should serve are questions for all educators and not just those drawn from the fields of science and technology. Likewise the introductory exploration of 'holistic education' by Crawford challenges a subject based curriculum to its foundations. In its advocacy of curriculum integration and its concern for values education, an STS audience is always likely to be sympathetically disposed but science and technology educators are, to use Panwar's term, stakeholders. Just what might be involved in more creative integration Fensham (1991) discusses in a contribution to an earlier IOSTE Symposium. He considers how science education might have to change if science is to help service technological understanding. Referring to Layton's (1988) suggestion that science would have to take a different 'form' and to Harrison's (1989) claim that science concepts would need to have different 'shape', he asks 'how far are science educators prepared to go?' While acknowledging that it is difficult to be sure what kind of reformulation of science is required, he goes on to make some informed guesses but he still comes to the conclusion that it is unlikely that science and technology will develop the symbiotic relationship that has often been hopefully projected. Against this background it should be pointed out that Layton (1993) has discussed the place of technology in the general curriculum and argues that it may be unhelpful to think simply in terms of *either* separate subject technology *or* technology across the curriculum. He sees potential in a mixed economy in which there is a subject called technology and contributions from a range of other subjects, including science, all supportive of a culture of practical capability. Meanwhile, as expedient curriculum decisions continue, it is certain that, as pressures on the curriculum continue to build up, then the number of voices pleading for radical reforms such as those aired by Crawford will escalate. STS is itself a recent, reforming curriculum movement and it is good that papers at this Symposium challenged the *status quo* so that STS proponents are not allowed to degenerate into stakeholders defending a tradition.

One topic that did not feature in the written papers but which surfaced more than once in discussions arising from papers is a strong conviction that many university science courses continue to propagate a pure, narrow view of science

that leaves graduates intellectually ill-equipped to deal with the social issues of the kind that feature in STS studies. Through a failure to consider curriculum design appropriate for the year 2000 it was said universities are in danger of failing to produce 'cultured persons'. The perpetuation of traditional subject specialisation in universities is further seen as a disincentive for schools to engage in integrated studies which aim to give a holistic overview of complex issues facing society. Some participants see an 'invisible hand' of university academics wielding an excessive influence on school curriculum development through the entrance requirements they enforce, the nature of their degree courses, the style of their own teaching and the impact these factors have on the graduates that emerge, some of whom enter the school system as teachers. In the context of these opinions it is pertinent that few academics from science and technology departments of higher education were Symposium participants. Yet it will be noted that potent criticism of science curriculum developments in Australia comes from a leading member of the scientific research establishment (see Williams). Amongst some participants there was evidence of conviction that school curriculum moves towards more integration and 'holism' are unlikely to occur successfully without some accompanying movement in higher education. As a world organisation of some standing and with membership which includes leading national science and technology educators, IOSTE might feel a responsibility to adopt as part of its agenda the task of communicating these concerns to influential academics in higher education.

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STS cross curricular themes: environmental education; national\local development - within claims & strategies

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Summary

This review addresses the portion of the Seventh IOSTE Symposium that was a forum for the sharing of claims and strategies in STS cross curricular themes, environmental education, and national/local development. The 13 papers in this group were true to their charge, clearly describing significant educational undertakings already completed, in progress, and being contemplated world wide. The specific projects, programs, and recommendations discussed were involved with diverse but closely linked dimensions such as STS environmental education goals, curriculum development, materials development, teaching strategies, teacher training, assessment, and research findings.

Several areas of strong agreement emerged. These were the call for the concept of sustainable development to be a driving force in environmental education, the need for a sustained commitment to environmental education (e.g., every grade every year), the need for a more holistic, inclusive view of STS environmental education, the notion of environmental education approaches that promote acting locally and thinking globally, and the concomitant acknowledgment of the global nature of environmental problems and solutions.

There were also clear issues that surfaced. Among these were the desired structure of STS environmental education (e.g., environmental education in the subjects versus the subjects in environmental education), the role played by the cultural context of educational audiences, and the extent to which STS environmental education alone will change people's behaviour. Also, yet to be clearly determined is the nature of environmental education that is truly "future oriented."

Not surprisingly, some common problem areas were identified. First and foremost among these were how to most effectively and efficiently change the existing school curriculum, materials, teaching strategies, and evaluation methods. It also became apparent that this change becomes an increasing challenge as the scale of the change increases (e.g., from a single school to state or national level).

Introduction

The papers in this group communicate a very uplifting and positive message. The authors propose bold new directions for STS environmental education, describe projects, programs, and materials that have been found to be extremely successful, and make suggestions for new directions in educational research.

The authors have collectively projected a clear vision for what environmental education can and should be as we approach the turn of the century. They are to be especially congratulated for providing convincing rationales for their projects, programs, and recommendations. These rationales are impressively supported with citations from the relevant literature of STS environmental education.

At the same time, the papers point out the magnitude of the challenges we face in changing traditional science, technology, and environmental education outcomes, curricula, teaching strategies, assessment and evaluation, and teacher training. All of these key educational variables are embedded in the culture of education and society and reflected in the attitudes of teachers, students, and the population as a whole.

The nature of the interaction of the earth's systems also contributes significantly to this challenge of instituting change. As the paper by Stubbs and Anderson points out, environmental problems are not always simple and subject to local solution, but often subtle, intricate, improbable, with cause and effect separated by decades or more, and require international solutions. The American Association for the Advancement of Science (1993) speaks to this also in pointing out that the benefits and costs of proposed choices involve both long-term and short-term and direct and indirect consequences, and that the social trade-offs can be generational. Many people and societies appear to operate on only a short term local perspective when considering the necessity for change.

The papers are incredibly rich, touching for example the full range of target audiences from primary students to adults not attending school. Most importantly, however, these papers from 11 nations each brought their unique perspective to the symposium. The resulting diversity and stimulating richness makes them compelling reading. This combination of breadth, depth, and multiple perspectives may only be attainable through international symposia such as those sponsored by the IOSTE. It continues to become increasingly evident that the more we learn about each other, the more we find we have in common -- the world has much to offer to the world!

Sustainable Development

The concept of sustainable development was a highly significant thread connecting more than half of the papers in the cross curricular themes and environmental education group (de Jong, Piew, Rajagopalan, Saez and Riquarts, Stawinski). This is not a new idea, but perhaps one whose time is finally drawing near.
In reporting one of the now famous conclusions of The Club of Rome, Meadows et al. (1972, p. 29) state, "It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his individual human potential."

While operational definitions of this concept show slight variation in the papers, one provided by de Jong (p. 434) seemed to clearly capture the contemporary essence of this powerful idea. "Sustainable development means that people fulfil their needs without taking away the possibilities of people elsewhere, of future generations and of other living species to fulfil their needs." Some rather subtle differences appear to make this current vision of sustainable development even richer than the 1972 concept. In particular, the inclusion of other living species seems to reflect a growing sense of connection of humans with the global environment. This is also the viewpoint shared by other contemporary writers such as Bowers (1994).

The overriding importance of the sustainable development idea was expressed most often when authors were speaking of the desired outcomes of environmental education and the nature of the curriculum itself. There appeared to be agreement among the authors as to the desired student outcomes from environmental education. Basically these consist of a balanced combination of factual information or knowledge (e.g., ecology, earth systems, economics, politics), decision-making skills, problem-identification skills, and problem-solving skills. It appears to this author that the shared commitment to the concept of sustained development may well have helped to more clearly identify the desired student outcomes.

Perhaps a reason that it has taken so long for the concept of sustainable development to begin to actually start driving environmental education is the translation of that desired state into the "nuts and bolts" of curriculum, instruction, and assessment. It is one thing to say its a good idea and quite another to design and implement a program whose "graduates" can cause it to become a reality. While the progress has been substantial, much remains to be done. A focus on the design, implementation, and assessment of such programs might in itself represent a powerful theme for a future IOSTE symposium, publication, and/or interest group.

Educational Change

A central theme to all of the papers in the group was educational change - change, for example, in the desired outcomes, curriculum, instructional materials, teaching strategies, and teachers and students attitudes. Many of the problems, issues, and challenges discussed pointed out the critical need to better understand the nature of the change process in both education and society.

Some very interesting discussion of the change process was included within the papers. Saez and Riquarts, for example, discuss change from the perspective of continuous versus discontinuous. It is pointed out that change is often enthusiastically sought or accepted when it is perceived as potentially resulting in a better way to achieve an already accepted goal. On the other hand, resistance is often encountered when introducing changes that are perceived to change the goal from that which is institutionalized. This type of change, referred to as discontinuous, is therefore considerably more difficult to achieve. Examples of such discontinuous change from the papers included Saez and Riquarts proposed conversion to a future-oriented curriculum and Gravenberch et al. effort to move teachers to a constructivist-based teaching approach.

This idea of the "institutionalized" nature of educational goals, expectations, teaching strategies, curricula, assessment, etc. being a major "hurdle" to be cleared is widely supported in the literature. Waks (1994, p. 44), for example, suggests that on the larger scale, "So despite the authorization of STS efforts by professional teacher groups, schools and colleges have received *no general authorizing charter* to promote social and political participation, as they have to promote employment and public order." Tobin et al (1994) cite such variables as beliefs of colleagues and students among an array of sociocultural factors creating an apparent resistance to change. They conclude (p.245), "A culture seems to sustain traditional practices in which are embedded problems that are the foci for reports that urge reform."

Several authors identified what appear to be generalizable strategies that they believed helped to overcome such institutionalized barriers and promoted significant change among teachers and in some cases students. Cohen et al., Cox, and Saez and Riquarts, for example, describe the potential benefits of experience-based or situative learning. Another strategy is the use of extended interaction time (e.g., one year) for teacher training or retraining. This in fact is a central feature of the projects described by Cohen et al., Cox, and Stubbs and Anderson.

Two other potentially useful techniques are described by Gravenberch et al. These are the embedding of new teaching strategies in new curriculum materials and encouraging teachers to use an eclectic approach to select existing materials and activities to move towards a new set of learning outcomes. The latter two strategies appear to make the change process more "teacher friendly."

All of the strategies described are highly consistent with the widely held view of the critical importance of the teacher's participation in the change process. Jozefzoon (1986), for example, contains numerous examples of this in studies of curriculum projects conducted in the Netherlands.

The importance given the process of educational change in the papers suggests several thought-provoking questions. Is there a need for more research in the area of the educational change process as it applies to science, technology, and environmental education? Are curriculum developers and other educational decision makers adequately informed as to the existing knowledge base in the area of educational change? Is the topic of the process of educational change in itself an appropriate theme for a future IOSTE symposium, publication, or interest group?

Cross-Curricular Nature of STS Environmental Education

Directly or indirectly, the papers reflected the perceived necessity of STS environmental education assuming a more holistic or inclusive perspective. This concept has gained increasing international support through time. More than 20 years ago in Meadows et al. (1972, p. x-xi) the Potomac Associates wrote, "These seemingly divergent parts of the 'world problematic,' as The Club of Rome calls it, have three characteristics in common: they occur to some degree in all societies; they contain technical, social, economic, and political elements; and, most important of all, they interact."

The need for a holistic approach and alternative possibilities for achieving it have been central focuses at IOSTE symposia. An especially eloquent argument for this wholeness approach was made by Nachtigall (1988) in a keynote address at our 1987 symposium in Kiel, Germany.

While a frequently stated goal is to have environmental education for every student in every subject at every grade level, we are reminded by authors such as Devadas and Tiagha that the need is for all members of society, not just those engaged in formal schooling.

How to best achieve this comprehensive and holistic perspective is an issue. The papers reflected a very diverse set of recommendations and examples. The largest question that seems to be present is whether STS environmental education should be infused into all of the subjects or the subjects should be integrated into STS environmental education!

Other questions raised include, should there be specific environmental education courses in the curriculum? Should technology education include environmental education? Should environmental education include technology education? Is environmental education a part of STS education? Is STS education a part of

environmental education? We have many such provocative questions to be addressed, discussed, and investigated in the future.

It appears to be typical to examine STS environmental education from the frame of reference of science education. As an alternative approach, the papers by Rajagopalan and Santhakumar and Saez and Riquarts raise a number of very significant questions regarding STS environmental education when examined from the perspective of technology/engineering education. Rajagopalan and Santhakumar make a particularly strong argument from the perspective of basic concepts, approaches, and methodology to integrating ecology into the technology curriculum. Among the key concepts identified is the interdependence among social, economic, ecological, and technical considerations. A human ecology framework is called for.

Curriculum

Since the topic of curriculum is very broad and overlaps with teaching strategies, the development of materials, and teacher training, it was a central focus of many papers (Cohen et al., de Jong, Gravenberch et al., Piew, Rajagopalan, Saez and Riquarts). These authors either explicitly or implicitly identified what they consider to be the most important characteristics of a successful environmental education curriculum. A synthesis of these characteristics follows.

Characteristics of Successful Environmental Education Curricula

Includes values, skills, and knowledge

Expands beyond the biophysical aspects to become truly holistic and interdisciplinary, including such perspectives as economic, political, technical, social and cultural

Integrated/infused into all school subjects and grades and includes the out-of-school population as well

Designed to promote action on relevant local and regional issues as well as global thinking

Provides factual knowledge and addresses the development of functional skills (e.g., decision making, problem solving) and changes in opinions and attitudes

Carefully planned and coordinated so that it moves from students' immediate environments towards larger scale deliberations and actions

These characteristics in various combinations have received long-term support in the literature (Eulefeld, 1979; Science Council of Canada, n.d.; National Research Council, 1994).

A number of very interesting environmental education projects, materials, and teaching strategies are described within the papers. Some that seem to have an especially good "fit" with the previously identified characteristics are briefly cited.

An example of a highly focused yet open-ended curriculum unit is "Chlorine in Society." It is designed to be infused into upper secondary chemistry instruction in the Netherlands. de Jong describes how this unit specifically examines the manufacture and use of chlorine, along with the pros and cons of the associated chemical, environmental, and economic issues. The arguments regarding the issues are openly discussed as combining facts and values.

As is often the case, this curriculum unit carries a powerful teaching strategy message embedded within it. One of these is to actively involve students in debates regarding the future of chlorine's use.

There are two especially unique aspects to this project. One is the emphasis on the idea of sustained development, while the other is a heavy curricular use of the concept of integral chain management. de Jong (p. 430) provides a concise description of this concept. "Integral chain management seeks to close the life cycle of a product as much as possible and keep residual emissions and residual waste streams within acceptable limits."
Among others, the American Association for the Advancement of Science (1993) is supportive of this type of approach to help students develop an understanding of the nature of the designed world.

The "Implementing Environmental Education in the Subjects Project" is a national lower secondary level project in the Netherlands described by Gravenberch et al. The goal of this SLO undertaking is to support teachers in infusing environmental education into the regular curriculum utilizing already existing materials. The net result is a curriculum including environmental education that also reflects many of the desired characteristics previously cited.

A fascinating feature of this project was the adoption of the constructivist view of learning for materials, instruction, and assessment. This is a widely promoted perspective from the arena of learning psychology. The adoption of the constructivist view mandates significant changes in the way in which teachers interact with their students. Achieving this role change from deliverer of information to one of facilitating the students' construction of their own knowledge is reported to have been more of a problem than anticipated. The teaching strategies sought were the more student centred approaches such as concept mapping, group or cooperative learning, and field work.

A number of interesting findings from project research are reported. Among them, not surprisingly, is that teachers were found to be more willing to change the curriculum than their teaching strategies. This appears to be a good reason to consider embedding the desired teaching strategies in the "new" curriculum materials. Other findings relevant to this section include the reported difficulty of working with the diversity of teachers across the entire curriculum and greater difficulty in instituting change in upper secondary when compared to lower secondary.

Teacher Training

One highly significant point that emerged from the papers is the similarity of the attributes of successful teacher training programs for environmental education and the instructional programs provided for students. For example, teacher training programs should provide the opportunity for a holistic learning experience where the importance of social, cultural, and economic information is examined to more fully understand environmental issues. Cohen et al. and Saez and Riquarts, among others, pointed out the importance of modelling in teacher training, where teachers generally replicate the strategies, type of assessment, values, ideas, and knowledge they experienced during training.

Another common message is the critical role played by teachers in curriculum change. Therefore highly focused teacher training is an essential component of any curriculum change plan.

An illustrative example may be helpful. Saez and Riquarts call for environmental education programs that provide the knowledge and skills for citizens to operationally pursue the goal of sustainable development. A critical dimension of the teacher training to achieve this would be a somewhat new view of evaluation. They propose a view to be developed in an action-training context. Evaluation here is part of the learning process itself. An action is taken, its impact evaluated, and modifications made for future actions. They assert that such a cyclical approach prepares students and teachers to operate effectively in an unknown future. This is one specific and potentially powerful response to the frequently ask question, "How we can prepare students for an unknown future?"
Papers by Cohen et al. and Cox focused specifically on teacher training projects for inservice (i.e., practising) teachers. These two projects had much in common, and these commonalities represent especially significant considerations for those planning such projects.

Both projects featured field-based team learning opportunities with experience-based learning a cornerstone. The work with the teachers also was ongoing over the period of a full year. During this year, the teachers were involved in short-term workshops of a day or two duration and intensive extended summer field experiences. In addition, both projects were cooperative undertakings involving

universities and other public agencies.
These shared features are those cited by both authors as having most significantly enhanced each project.

Cohen et al. describe "The Tropical Rain Forest Experience" a project primarily designed to increase K-12 teachers' knowledge of the rain forest. The University of Indiana and the Indianapolis Zoo, with assistance from the University of Costa Rica, were the collaborators. A unique and provocative aspect of this project is the contribution of the "adventure aspect" of the distant rain forest experience in Costa Rica to the learning and professional growth of teachers.

The two projects described by Cox both involved the local environment of the participating teachers. In one case Portland State University collaborated with the United States Forest Service and in another with the U.S. Environmental Protection Agency. Agency and university personnel trained teachers to engage in field data gathering. Teams of teachers then spent extended periods of time working in the field under the supervision of the agency. The work in forests and urban wetlands provided the teachers with a "real" science learning experience that empowered them to provide the same kind of experience, with the data able to be used by the agency, for their students.

Not unexpectedly, both projects reported significant changes in teachers' teaching strategies and described some curriculum changes and materials developed by individual teachers.

Materials Development

Only the paper authored by Stubbs and Anderson focused specifically on materials development. It described the GLOBE-NET project in the U.S.A. where global change instructional materials were collaboratively developed by a team composed of teachers and research scientists. The materials were designed for use in grades 4-12. Among the topics explored are global climate, the atmosphere, water resources, oceans, biodiversity, deforestation, sustainable agriculture, and urbanization. As is typical in the development of materials, some new instructional approaches were also incorporated.

One of several unique and highly significant features of this project was the development of conceptual schemes to guide materials development. An example of a conceptual scheme for global climate change is included in the paper. Another useful feature is a set of materials development criteria, which is also included in the paper.

The GLOBE-NET project shared two commonalities with projects described in other papers. First, it was a collaborative venture; in this case involving teachers from the states of North Carolina and Minnesota and faculty from North Carolina

State University and the University of Minnesota. Second, it incorporated long-term interaction (e.g., summer and academic year) among participants.

While the GLOBE-NET materials, like those produced by national curriculum development groups in other countries, are targeted for widespread dissemination, projects such as those described by Cohen and Cox targeted the development of materials by participating teachers primarily for use by those teachers.

National/Local Development

The papers by Akpan, Devadas, Olariu and Caracaleanu, and Tiagha formed the subgroup addressing national level goals, concerns, and development efforts. The paper by Piew also assessed the effectiveness of a national environmental education program in Malaysia.

The overriding theme common to the papers is the critical importance of science, technology, and environmental education efforts being implemented in the contextual reality of the targeted students and citizens. This critical importance of culture was also an important conclusion in the cross curricular themes/environmental education papers and therefore represents one of the most significant claims to emerge from the entire group of papers.

If the environmental education effort is not meshed into the cultural context, the authors identify various potential negative consequences. One is that environmental, science, and/or technology education will be viewed as primarily academic (e.g., for examination purposes only) rather than for application in the decision making that influences citizens behaviour and national development. Another is that positive lip service is given, but personal beliefs, values, and actions remain unchanged.

Piew makes the rather surprising statement that a cognitive oriented Malaysian environmental education curriculum that appeared to have a balanced approach across biophysical, social and cultural environments created little if any change over more than a decade. This was in terms of both rate of environmental degradation and public attitudes towards the environment.

Citing a higher level of success in neighbouring Singapore, Piew makes the provocative suggestion that perhaps environmental legislation and enforcement needs to be implemented in concert with environmental education. This certainly appears to be a topic well worth depth exploration in future IOSTE undertakings.

Cultural Roadblocks

Akpan cites numerous specific examples of cultural roadblocks (e.g., superstitions, taboos) to the development of science and technology in some African countries. These same roadblocks impact science and technology education in terms of the education potentially being viewed as purely academic and limiting career choices among students. Akpan suggests in fact that African students face the challenge of operating from a tricontextual perspective, attempting the demanding task of integrating religious, native, and scientific contexts. As one possible solution Akpan presents a teaching/learning model known as the Sieve process that integrates these contexts and is aimed at facilitating the replacement of misconceptions.

Authors Akpan and Devadas both noted the especially negative impact of cultural and social roadblocks on women. This impact is not limited to the nations of these authors, as clearly pointed out for instance by the Science Council of Canada (n.d.).

Devadas describes the creation of a program, Home Science, specifically designed to transfer technology to women in India. The wide ranging potential contributions to health, family planning, nutrition, and elimination of poverty are highlighted.

National Infrastructure

Tiagha identifies science and technology education as a key to the national strengthening of human capacities, institutional infrastructures, and physical infrastructures in Ethiopia. The concept of sustainable growth and development is a central idea.
The creation and development of a systematic national education network for energy and the environment is the focus of the paper by Olariu and Caracaleanu. The network is intended to impact users, specialists, and experts in Romania.

Conclusions

The papers collectively yielded a number of clear, powerful, and potentially useful conclusions centred on claims and strategies. Among these are the following:

1. Science, technology, and environmental education programs must be integrated into the fabric of the total cultural context in order to yield maximum educational impact.

2. The need for effective environmental education is perceived to be of increasingly high priority internationally, and by necessity, these educational efforts must be global in vision while able to be operationalized locally.

3. Environmental education must become more holistic and inclusive in order to adequately achieve its desired outcomes. It must be a component of science and technology education and technology and science education a component of environmental education.

4. Successful STS environmental education program implementation must take into account several important aspects, especially curriculum development, materials development, teacher training, and assessment/evaluation.

5. Implementation of successful environmental education become increasingly challenging as the scope moves from local to regional to national to international. Much research is needed in this area.

6. Environmental education programs must be comprehensive, not only covering all students in all subjects at each grade level, but delivered to all members of society.

7. Collaboration among schools, agencies, governments, businesses, and other "players" contributes significantly to the design, implementation, and impact of science, technology, and environmental education undertakings.

8. Teacher training and retraining programs have been found to have benefitted from long term professional contact of one year or more.

9. Environmental education should foster the achievement of global sustainable development.

10. Environmental education should prepare citizens for the future by thoughtfully engaging them in the present,

11. Steps need to be taken to provide increased opportunities for participation in STS environmental education by women and other underrepresented groups.

12. Expansion and utilization of the knowledge base regarding the nature of educational change is of critical importance in the implementation of new or revised science, technology, and environmental education programs.

These 13 papers have given us many potentially powerful and widely applicable claims and strategies. These relate to the full range of educational undertakings - curriculum, teaching strategies, teacher training, teaching materials, educational goals, philosophical underpinnings, assessment/evaluation, and collaboration. Our challenge is to critically examine and question our own practice and vision in light of these claims, strategies, and programs. Once again, we have much to learn from each other!

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S\T-education: contents and teaching methods - within claims & strategies

Lessons from the history of science education: can they be ignored?

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Summary

The 22 papers given at the 7th IOSTE Symposium which were concerned with 'claims and strategies' about 'content and teaching methods' in respect of 'science/technology education' are reviewed under themes which are common to them. The manner and extent of the overall address to these themes are critically addressed against a background of the general literature of curriculum change. It is concluded that, in several key respects, these papers partially overlooked the implications of that literature. The consequences of this are evaluated and proposals for future action are made.

Introduction

There seems to be a general consensus of view in the science education community that, in order to help meet the needs of society, there should be a closer relationship between science education and technology education (UNESCO, 1994). The interface between these two, when they are considered as separate cognate areas, is a matter of some complexity (Gilbert, 1992). If both separately incorporate societal aspects, examples being a discussion of how science is socially organized and how decisions on the importance of problems requiring technological solutions are socially arrived at, then their interface should represent a novel interpretation of the meaning of 'science, technology, and society' (STS) education (Solomon & Aikenhead, 1994). The nature of such an interface will be governed by views held on the respective natures of science and technology *per se*, on the aims for science education and for technology education which are derived from these views, and by the ways in which an address to the latter are organized within the school curriculum.

An analysis of the papers which are focused on claims and strategies concerning content and teaching methods in respect of the science education/technology education interface reveals a series of distinct themes. To start with, there is a belief that little can be achieved without a general review of curriculum and pedagogy in many countries. This review will have to include a critical, indeed sceptical, analysis of the needs for science education. Within and following this analysis, there is some agreement that classroom-based research should take place. The relationship between science education and technology education

within the curriculum must be explored, this being conducted with due regard to cultural sensitivities. With the groundwork established, the organization of curriculum development is seen to be problematic by many authors. The production of novel curriculum materials is seen to be the key to successful change, although, for some, this cannot be divorced from teacher development.

The need for curriculum change

Despite several decades of attempted reform throughout the world, science education is in a state of crisis. The tension between viewing it as a route to general education for individuals and as a route to the economic welfare of nations remains unresolved. The content and organization of the curriculum are heavily influenced by the interests of professional scientists. In the case of the Developing World, the examples used to illustrate that content in textbooks and in the classroom are all too often still drawn from the contexts of scientists in the Developed World. Because of the great expense of conventional laboratories, and the lack of suitably educated teachers, classes in all countries are often very large. As a consequence of this teaching is often didactic in style and learning is by rote. Examinations emphasise the recall of this content (Fensham, 1985).

Whilst many young people are willing to submit to this ordeal because it may offer an avenue to more highly paid jobs, they see it to have little relevance to their personal development. Few persist with science education for its own sake beyond the years of a compulsory curriculum. Girls, in particular, give it up at the first opportunity in many countries (Kelly, 1981).

If science education is to attract and retain the intrinsic attention of young people, the case for substantial curriculum change seems unchallengeable.

Science education and technology education

One avenue for reform must be through a closer relationship between science education and technology education. Not only does the latter offer a more immediate route to jobs in most economies, but its examples may add interest, relevance, and focus to the former.

In a paper on national educational policy formation in post-apartheid South Africa, Kahn (1994) analyses the nature and consequences of the separation of the forums for deciding on the curricula for science education and for technology education. Given the pressing nature of the problems of South Africa, even by general international standards, this separation seems potentially highly damaging both to economic development and to the coherent personal development of students. In contrast, Hunt and Russell (1994) point to a cooperation between those in science education and those in technology education, in the introduction

of the General National Vocational Qualification (G.N.V.Q.) examinations which bridge the divide between 'academic' science courses and 'vocational' technology courses in the U.K. Whilst this association is seen as being most important in respect of the scientific ideas which underpin 'high technologies' (biotechnology, remote sensing, new materials), Martin (1994) points out the great value, both from the point of view of idealism and of practical implementation, of forging links between science and 'intermediate' technologies. Finally, at the lowest level of generalization, Gilbert and Boulter (1994) suggest that the cross-curricular theme of models and modelling may bring science education and technology education more closely together.

These papers do span the whole spectrum of scope of impact, from mechanisms for national policy formation, through the nature of the contents to be related, to the use of one particular device to effect a linkage. The nature of bridges, at all levels of generalization, have been perceived, but not on a worldwide basis. Whilst other papers do touch on these matters, it is surprising that more do take this central issue as a core theme.

Meeting the demands of society

The need for an on-going process of curriculum review and development in science education, if it is to more closely meet the needs of society, is reflected in several papers, with these elements often being intertwined.
Lehri (1994) makes a strong plea for science education to become more 'practical, relevant, and appropriate' (p. 511). This general improvement in the quality of science education, for that is what is seen to be needed, is to be realisable, in the case of India, by the adoption of a series of strategies. These will include the adoption of 'guided discovery' teaching and learning methods built around practical kits of local relevance, the conduct of curriculum development around modern themes which link science and technology (e.g. remote sensing, biotechnology, computers), and through the holding of science fairs and exhibitions. Perhaps most importantly of all, particular attention will be paid to the interests and concerns of girls and women.

Töldsepp (1994), writing about chemical education in Estonia, using evidence supplied by a survey of schools, calls for a substantial reduction in the content load of the curriculum and for the adoption of a broader range of teaching styles to enhance student motivation. The production of curriculum materials in Estonian, presumably in contrast to Russian, is seen as likely to encourage general cultural development, whilst the use of local illustrations should support the development of the national industrial base.

The theme of active learning, which underpins the papers by Lehri (1994) and by Töldsepp (1994), forms the centrepiece of the contribution by Kaersenhout and Tan (1994), who report on the introduction of a practical skills test into the

pre-university examination in Suriname. This development is placed within the broader context of curriculum renewal in Suriname, as the legacy of the former colonial power (The Netherlands) is built upon/ overcome, in a review of challenges and responses by Marshall, Kaersenhout, Stirling, and Tan (1994).

The triplet of modernity, locality, and activity, are thus put forward as the keys to a more successful curriculum.

Advanced science education for all?

However, the core issue remains: successful in what respects? Fensham (1985) has demonstrated that a science curriculum which is both progressive (i.e. which runs throughout the years of a compulsory curriculum for all students) and scientistic (i.e. one which is derived from, and supports, the interests of professional scientists) is inherently unable to meet all the range of demands placed on it.

Papers in this section approach this issue from a variety of directions. Both Lehri (1994) and Töldsepp (1994) see there to be a need for advanced science education for all if national industrial development is to take place. However, this view is contested. Franco (1994), writing about Brazil, but in a way which seems capable of extrapolation to many developing countries, is very doubtful over the wisdom and practicality of seeking to introduce a science education which solely or largely reflects the interests of modern science-based industry. Given the financial outlay involved, it seems likely that such provision as can be made will be colonized by the already-wealthier sections of society, whilst it is doubtful whether the existing (and projected) economy will need the skills so produced. Bhattacharyya (1994) makes an allied point: the high level of expenditure which advanced science education entails in India seems to lead to little return to the country. There is a substantial 'brain drain', as skilled personnel migrate to economies offering better equipped resources for research and higher personal rewards.

The use of scientifically skilled personnel within a country is also a subject of discussion. Bhattacharyya (1994) laments that many trained scientists work in technology and engineering, the author being concerned about the availability of high quality staff for the maintenance of continuity in scientific research. Hunt and Russell (1994) take a different view, providing an analysis of the needs of employment in various technological occupations in respect of a background in science. They go on to outline the development in the U.K. of a school leaving examination in which students can study science within the context provided by such occupations. In their view, the provision of science education in support of technological activities in industry is entirely legitimate.

What does seem to be overlooked in these analyses is the need for the

development in young people of a critical appreciation of the social dimensions to science and of technology. Economic analyses, used as a basis for determining the possible nature of the science curriculum, whilst necessary, are not sufficient.

Curriculum development and implementation

If the curriculum is to reflect a broader set of influences and is to support a more active approach to learning, how is it to be developed and implemented? Fullan (1991) is clear on this matter. In order to be of a sustained influence in schools, a given curriculum development must: meet that consensus of needs on which all stakeholders (e.g. students, parents, industry, teachers, headteachers, government) can agree; be based on the incorporation, refinement, and extension of good practice in schools; be clear in its ambitions; be capable of realization in the average school within the average school budget; allow sufficient time and opportunity for teachers to be actively involved in the development of the innovation, and for them to assimilate and accommodate the new demands. In what way, and to what extent, are these issues addressed in the papers in this section? The remaining parts of this paper address this question.

Cultural sensitivity

If consensus of interest between the stakeholders cannot be approached directly, it can be done iteratively by actively considering the interests of diverse cultures within a given society. However curriculum development is organized and funding, it must, in a post-modern world where ethnic, cultural, and religious, boundaries are fluid, pay due regard to the sensitivities which this complexity engenders (Hargreaves). There are two papers, both alert to this issue, in this section. Finegold (1994) outlines the evolution of a staff induction programme concerned with the absorption of immigrant teachers and students into Israel: here ethnic and cultural differences have to be assimilated and accommodated. Timmermans (1994), in contrast dealing with ethnic and religious differences, gives an account of a curriculum development project in The Netherlands concerned with the highly vexed question of sex education.

Even those countries which were historically portrayed by their leaders as being culturally homogeneous are now acknowledging their actual inherent cultural diversity. In many cases they are also accommodating the influx of hitherto-alien cultures. The scope and complexity of STS work in these environments can only grow and deepen. The papers presented show a suitable sensitivity to this set of issues: it is surprising that more papers in the section do not explicitly do so.

Classroom-based research

The need for classroom-based research to precede, or be closely associated with, developments in the science curriculum, including the teaching methods used, is reflected in three papers. Gilbert and Boulter (1994) outline an enquiry, conducted in a U.K. primary school, into the discourse which surrounds students' activities to construct explanatory models of an eclipse in a series of science lessons which stem from the recently-introduced National Curriculum. The lesson to be drawn from this paper is that any change in teaching method, or indeed in curriculum emphasis, must pay due attention to the changes in classroom discourse which are entailed by it. Cross and Birch (1994) report on the research undertaken in association with the introduction of small ('palm top') computers into a U.K. primary school. Here, changes in what was done and how it was done, in the classroom, are chronicled. Cross and Harrison (1994), in a contrast of scale to the other two papers mentioned above, give an account of an interview-based study, conducted in U.K. primary schools, into the issues and factors which teachers believe control efforts to raise educational standards there in respect of the teaching of technology.

Of the 22 papers reviewed, it is only these three which give primacy to classroom research as preceding, or being concurrent with, curriculum change. It may be just coincidence, but these three papers did come from one country (the U.K.), with it's strong tradition of empiricism and iterative change, and did make use of observation and interview techniques.

Materials development

The view that curricular issues in the science education/technology education field could be addressed by the production of packs of materials for use by teachers and/or students is widespread, as is reflected in the number of papers which report such developments. Den Ouden and Gray (1994) outline the educational possibilities which arise from the reclamation and subsequent documentation of ancient technologies, here found in north Africa. Martin (1994) discusses the contribution that a specialist centre, here concerned with intermediate technology, can make to the production of curriculum materials. De Munk (1994) shows how specialist scientific research knowledge can be used as the basis for the production of materials for laboratory and fieldwork use. An advocacy is made for the production of packs of materials for teachers (Waarlo, 1994), for the use of materials which are based on local contexts (Töldsepp,1994), and for the production of blueprints for student materials (Krsmanovic, 1994).

The possibility that these materials might not lead to actual curriculum change, but merely the substitution of one set of knowledge for transmission by another such set, figures little, if at all, in the accounts contained in these papers. The

necessity for concomitant teacher development is not evidently widely appreciated.

Teacher development

Finegold (1994) does discuss the value of mentorship i.e. the provision of support for a teacher on a one-to-one basis by other, more experienced, teacher in the classroom. This view supports the model, put forward by Bell and Gilbert (in press), that teacher development consists of an admixture of personal development, social development, and professional development. At a higher order of generalization, Waarlo (1994) points to the significance of a lack of follow-up, and teacher education, funding for a pan-EC curriculum development project. Inter-national cooperation does seem a way forward for curriculum development, especially for small or impoverished countries, provided that cultural sensitivities are respected and that support for the development is sustained for long enough for the innovation to be assimilated. The search for cheap, efficient, and effective, means of supporting teacher development is continuous: Hossain (1994) and Lehri (1994) point to sustained attempts to use 'distance learning' approaches. This does seem a pragmatic solution to very large scale problems, in physically big, and poor, countries. Alas, the personal and social element of the development of the teachers is almost certain to be unaddressed in distance learning.

Given the centrality that major accounts of curriculum development give to systematic teacher development (Fullan, 1991; Hargreaves, 1994) it is surprising that closer attention is not paid to this issue.

The role of curriculum development agencies.

How the development of ideas, classroom approaches, and materials, is organized is of central importance in bringing about successful curriculum change. This theme, of all those which falls with the remit of this section of the Symposium, attracted most attention. The papers point to a wide range of agencies, and groupings of agencies, which may be, and indeed are, involved in curriculum development.

Three papers point to the long-standing, and still centrally important, role of universities in most, if not all, countries. Nurulazam and Sulaiman (1994) describe a computer assisted learning package, concerned with the concept of energy, developed by university staff, but say little about the process of that development. Kaersenhout and Tan (1994) give an account of how university staff in Suriname worked with those in other educational agencies to provide a much-needed opportunity for school students to engage in laboratory practical work. Krsmanovic (1994) shows how staff of the University of Belgrade

developed packages describing research activities which could be carried out in the school laboratory and elsewhere. Taken together, these three papers show university staff making their expertise available to schools, albeit in respect of problems and provisions which are of central importance to universities.

The growing role of non-governmental organizations (NGOs) in curriculum development is reflected in the rich crop of papers on this theme which the Symposium produces. Hunt and Russell (1994) point to the significant contribution being made to curriculum development by a charitable organization in the U.K.(the Nuffield Foundation). Kahn (1994) remarks on the impact being made in South Africa by the World Union project of the international ORT organization. Perry (1994) describes how a national NGO in the U.K. (The Royal College of Art), acting as a collecting point for contributions from industry, is facilitating a major curriculum development project in technology education. Individual industrial companies, acting alone or through a bridging NGO, are making a significant contribution to a broadening of the science and technology curriculum by sponsoring national competitions and awards: Rice (1994) gives examples from the U.S.A., whilst Lehri (1994) does so for India.

Marshall, Kaersenhout, Stirling, Tan (1994) describe the way in which one country (here Suriname) makes use of the expertise available in another country (here The Netherlands). Such bilateral cooperations are relatively common where countries have ties of language, culture, and structure of educational provision.A case study is presented of the adaption of central government curricula by a regional government (McClune ,1994). However, Waarlo (1994), in a paper which must surely point the way to the future, gives a case study of a multi-national cooperation, funded by a continent-wide agency (here the E.U.).

What is so encouraging about the papers on this theme is the diversity of types of organization that are becoming involved in curriculum development. This must surely allow for the recognition of a range of concerns about, and proposals for, the science curriculum.

Discussion

In overview, the papers in this section do address much of the agenda of issues associated with developing a science curriculum to meet the ever-broader demands of society.

In respect of claims, there is widespread support for the process of review to lead to more practical, relevant, and appropriate curricula. There is a call for the inclusion of modern science in school curricula in support of modern industry e.g that concerned with biotechnology, remote sensing. In respect of strategies, there is a evidence of the increasing, and more diverse, role being played by Non-Governmental Agencies (NGOs) in curriculum development. One major

emphasis here is on the production of materials for use by teachers and/or students, whilst another is on the use of local contexts (and languages) within which to present ideas. In respect of content, it is severally proposed that this is drawn by an analysis of technologies: ancient technologies, modern intermediate technologies, and high technologies. In respect of teaching methods, advocacy is made of the inclusion, or extension, of practical work. Extra-curricular activities are also seen as a major avenue to the reform of science/technology provision. Distance learning is seen to have a role to play in teacher development.

There are, however, additional questions. What contribution would a reformed curriculum make to students' personal, as opposed to pre-employment, development? It does seem unlikely that young people, beset with a wide variety of demands for their attention arising from the complexity of the modern world, will pay any real attention to science/technology education unless it offers some address to those concerns. If significant change in the curriculum is to take place, what is to be the pattern of relationships between, and responsibilities of, the major 'stakeholders' i.e. schoolteachers, government officials, parents, industrialists, and, of course, the young people themselves? Substantial additions to the literature of curriculum change await writing. If widespread curriculum change is to take place, how is the research and development to be funded? The patterns of existing, and possible future, relationships have to be established. If new content is to be introduced into the curriculum, how is the reduction in existing content to be arrived at? Unless this issue is addressed, schools will be faced with a 'sedimentary curriculum' i.e. one where, like a river, the waste of earlier activity falls to the bottom (of the age group) and becomes compacted. If new content is to be introduced, how is it to be arranged progressively within the curriculum? Principles for the ordering of content are still urgently needed. What role does group, collaborative, work have in the lexicon of teaching methods? Working alone, in competition, is hardly conducive to change attitudes and values.

The literature of curriculum development in science education, and indeed in other curriculum areas, is a rich source of advice, based on classroom-based research conducted at the time, into how successful curriculum change may be brought about and how failure may be avoided (e.g. Fullan, 1991). Some, but only some, of these lessons are reflected in the papers given in this section of the Symposium. Why is this? One can only speculate. Is it that science educators, who must, for credibility with the science community, have a science background, lack a social science perspective on the task of curriculum development and implementation? If this is the case, then in-service education is called for. Is it that funding agencies are not persuaded of the need for research in science education? If this is the case, then such agencies must be lobbied. Is it that the conventions in the reporting of the results of science education research do not lend themselves to a ready perception of the transferability of results to other contexts. If that is so, the editors of journals must consider what active measures they can take (Gilbert, 1994)? Is it that curriculum developers do not

have access to the reports of research? If this is the case, then international agencies should consider the establishment of more document centres which are widely advertised. One thing is certain: if the lessons of the past are not heeded, then the errors of the past will be endlessly repeated. In the case of science education, which is very expensive, this could be disastrous for many countries.

If future IOSTE meetings are to build on the achievements of the Seventh International Symposium, then perhaps papers in this section could usefully reflect three developments. Firstly, an increased awareness that curriculum development can only safely take place in the wake of extensive classroom-based research. Secondly, that the participation of technology educators is needed to balance the present predominance of science educators. Thirdly, a closer address to the issues of curriculum change. With these three considered, the provision of guidance for change is a real possibility: without that consideration, only rhetoric will be produced.

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S\T-education: teacher education - within claims & strategies and strategies & empirical evidence

Review on Teacher Education

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Summary

The underlying theme of all papers reviewed in this section is that teacher education, their preparation to take the role of innovators is the key to successful reforms in Science Technology & Society (STS). Three main themes have been identified, under which the papers are organized. The first is STS teacher education in a changing society, a theme that emphasizes the relationship between a society-in-change and changes in teacher education policy. The second theme focuses upon the relations between research and practice in teacher education. The third theme addresses directly the relationship between curriculum development and teachers' professional development, in other words, the degree of teachers involvement in STS curriculum development. The general massage of most papers in this section is the need for new models of teacher education, which prescribe new infrastructures that support and empower teachers, thus producing teachers that are able to take more responsibility for their own curriculum development.

Introduction

Within the section of Teacher Education, 8 papers and one symposium, deal specifically with the issue. However, the problem of teacher education was raised implicitly and in somewhat indirect way in many other sections, and could be viewed as an issue that cuts across all the different sessions. The review refers directly to the above papers, yet an indirect mention is given to the concern expressed in other papers,.towards the education or preparation of Science and Technology teachers, as well as to actual teacher education experience in the field.

The key to successful reforms in all the different variations of Science Technology & Society (STS) was unanimously agreed to be the teacher, thus teacher education (whether preservice or inservice) their preparation to take the role of innovators, is regarded as a prerequisite to effective STS teaching and learning. Yet there are different emphases with respect to the framework, the philosophy or ideology and the role of the teacher as innovator. Accordingly three main themes have been identified, under which the papers are organized..

The first theme which is most congruent with the title of the symposium: Science and Technology Education in a demanding Society, highlights the relationship between a society-in-change and the changes in teacher education policy. The second theme focuses upon the relations between research and practice in the field of Science and Technology teacher education. The third theme addresses directly the relationship between curriculum development and teachers' professional development, in other words, the degree of teachers' involvement in STS curriculum development.

STS teacher education in a changing society

Touching upon the unique problems of education in Africa, Patrick Whittle of Malawi university surveys the curricula that were introduced into Africa at the turn of the century, which he characterizes as closely modelled on colonial power. In biology for instance, the examples given were of European flora and fauna, while industrial processes of limited relevance in Africa, were part of the science curriculum. Assuming that every country has its body of indigenous knowledge, which is more important than 'any imported' knowledge (Swift, 1992), these particulars have been replaced with local examples. Yet, the original emphases on examination-oriented curricula, which is based on factual recall and passive rote-memorisation has remained. African science teachers, as a result, have adjusted to this passive role of teaching western views of the world rather than discussing science or technology related to their own existential socio-cultural problems. Such 'grey' areas where there is no 'black and white' answers, make them feel insecure. It seems that Science teachers today are the limiting determinant of success of any science education reform.
An urgent need to provide effective and ongoing inservice support for science teachers is expressed in the paper, and of no less importance is the support for the science education teachers themselves (Ware, 1991).
The call to grant highest priority to science teachers' inservice courses, particularly for those of rural areas in the developing world, is voiced by another African, Brian Grey, from Western Cape university, in South Africa. His paper relates to the experience of 'KwaNgwanase school science teacher development project', and its implications with respect to some guiding principals for an INSET model.
Grey's idea was to develop an outreach programme, that supported surrounding schools, by providing them with kits of basic science teaching equipment. As the funding grew, a teacher-led support infrastructure, of workshops, meetings, and more equipment was established to cater for 23 primary and 6 high schools.

The key elements of this type of INSET were the following principles:

* Voluntary participation, yet subject to criteria, which were worked out by the project teachers.
* Responsibility for the organization and the running of all activities, taken by an.elected committee
* Creating time for sharing of problems and teaching ideas, within a system of regular teacher-led meetings, workshops and courses. Such infrastructure provided the basis for continuity, where teachers' ownership of the process was secured.

As a result of the project a high degree of commitment was achieved, with high attendance rate of teachers, and a growing request from schools to participate in the project.
Teachers feedback indicates a sense of support through involvement, increased personal and professional confidence, and with science teaching equipment in the schools, more practical work was done.

Besides providing support, the model created real space for teacher's initiatives to surface, take root and grow. With this came professional growth.
This Inset model presents a viable basis for providing an ongoing sustainable support for teachers in rural areas. However limitations of the model have to be faced. A system based on teachers resourcing each other, becomes limited where most teachers are uncertificated. Additional outside resources are necessary, yet it is critical that their use does not undermine the concept of teacher ownership or responsibility (MacDonald, 1993).
A major contributor to the effectiveness of the project was the slow contextually sensitive and reflective process of development. In conclusion Grey emphasizes the importance of providing sustainable in service support for science teachers, especially in remote and under-resourced rural areas, and in particular in the developing world.

The third study by Alan Pilay and Prem Naidoo, from the university of Durban Westville, reflects clearly the recent socio-political changes in South Africa.
Focusing upon the current model of curriculum development and implementation, both in schools but mainly in institutes for teacher education, they claim that the RDDA model, centrally planned by experts and then implemented in the periphery by teachers, has resulted in making the teachers function merely as technicians, as implementors of 'handed down' curriculum (Popkowitz, 1989; Olsen, 1982; Robottom, 1987).
Such teachers feel inadequate and incapable to deal with real problems. They become a culture of non-participators, disempowered teachers, developing apathy and resisting any form of collaboration.
Their argument is that in a society-in-change, there is no room for a top-down system. Instead, a model based on teacher participation in curriculum development processes, is required.
The University of Durban-Westville encouraged science student teachers to

develop curriculum packages based on Environmental Education, and to implement them at school. Both pupils and student-teachers benefitted tremendously. However, that was not the case of the practising teachers who were 'passengers in the process'. They seemed to have developed a dependency syndrome, requesting regularly the intervention of the university researchers. Moreover, even the science student-teachers, once qualified and functioning as practitioners, also failed to continue
with the process of curriculum development in their schools. This called for a further change, a transfer of the teacher education site from the teacher education institutions to the reality site, namely to the school.

A joint collaborative- participation of student teachers, qualified teachers and teacher educators was established, and an Action Research (AR) approach was applied. 'Water', as a most relevant theme was chosen, and a curriculum package was developed jointly (by the teachers and student-teachers) and implemented in the classroom by the latter. Thus within the AR framework, curriculum development and teacher development occurred together. The teachers become used to the idea of the curriculum as process that one adapts in school (Levi & Kahn, 1992) The teachers are given an opportunity to socially construct the world, in the way they see it (Berger & Luckman, 1967).

Two papers outside the section of teacher education, refer to their experience in teachers' development in collaborative frameworks. Michael Cohen from Indiana university, established a partnership with the Indianapolis Zoo. A program based on the Tropical Rain Forest as a theme, was found effective for teachers' personal professional development. The aim was to improve science and Environmental Education through the teachers' own experiential learning.

David Cox from Portland State university, developed a model of collaboration between high school teachers, university experts and governmental agencies. Teachers were engaged in field based research work, which was aimed to lay the foundation for integrated science curriculum development. The results indicate that the experience was a significant potential for teachers development, rather than for curriculum materials.

To sum up, the first theme touches upon the unique recent political changes in Africa, and the urgent need for educational reforms in the developing world, where science and technology teachers today, are the limiting factor for change. An urgent need to provide effective and ongoing inservice support for teachers is expressed, especially for those who live in the rural areas of the developing world. Different collaborative frameworks are advocated, between schools and university, teacher educators, student teachers and practising teachers, or between teachers, university, and the community. It is assumed that these would provide a sustainable support, and thus empower teachers.

Research and practice in teacher education

The second theme, which is the focus of the following papers, is based on the assumption that teacher education as a key for educational reforms, require comprehensive research in the field. More research studies are needed on STS teaching, that could have implications on how to improve STS teacher education, is the essence of the first paper. The second paper surveys the candidates, the preservice and inservice students, with the aim of improving our understanding of the target population. The third paper indulges in a philosophical ideological query over the rationale of the teacher education curriculum. The three papers in this section are from Nigeria, Canada and Germany.

Andrew Urevbu, from Benin University in Nigeria, poses a focal question: What kind of pedagogy is used in STS teaching?. His assumption is that if we want to improve STS teacher education, we cannot afford to ignore the current STS teaching in the classroom, workshop and laboratory (Gage, 1985).

This point is backed by an 'outside' paper by Joan Solomon, Linda Scott & Jon Duveen, from Oxford University England. Their findings indicate an over riding influence of the teachers views of the nature of science, on what their pupils come to believe, whether or not it is explicitly taught.

By an elaborate selection exercise, Urevbu chose two schools out of 100 'project schools', which thus became an object for his study. Applying classroom observations and teachers interviews, his findings indicated that STS curriculum which was enthusiastically received in all schools, by both pupils and teachers, is treated in most cases as an integrated curriculum, yet is hardly related to science technology and society.

His conclusions are that a closer relationship between teacher education institutions and the teaching profession has to be established in order to improve STS teaching. Classroom and laboratory settings need be developed. A 'wholeness approach' should be adapted both in teacher education and in the STS curriculum, that would overcome the existing fragmentation in the school sciences (Nachtigall, 1987). He calls for a closer articulation between academic and professional studies, by building educational psychology, guidance and counselling as well as communication skills, into the STS methods course. Regarding STS teaching as a political economical problem, there is need to incorporate political and economic demands in STS teacher education. To change the minds of those in power as to the issue of developing STS Teachers.

Ronald Hansen from Western Ontario university, Canada, questions the conventional wisdom and practice currently found in teacher preparation programs. His main assumptions are that

* Teacher education is the key to successful reform in Technological education,

* To improve teacher education, a deeper understanding of the process is required.

- Programs for teacher education should be designed on the basis of conceptual empirical and practical work.

Designing a study of teacher development, the project team examined the background and values of teacher candidates.
Using a case study approach and ethnographic methodology, they documented the students' life-history information (Cole, 1991; Goodson, 1988). The findings indicated that teaching has dramatically different meaning among students in the technological education program. A wide range of expectations was reflected through questionnaires and interviews, ranging from proactive attitudes of students who want to change the educational system, to others whose inclination was rather towards the human development aspect of education. The latter expressed a commitment to take guidance courses, to be better equipped in helping students face a variety of problems. They realized that teaching was a craft that combined competence within a specialized area, and service to the profession; "The main objective is not to teach technical specialization, but to provide an education".
Another interesting finding was that technology teachers, who mostly leave one career when moving into teaching, teach the way they work. In other words, their working experience influenced their thinking about teaching and learning
Based mainly on Zeichner and Gore literature (1990), Hansen concludes that teacher education programs should be constructed in a way that enables student-teachers to critically analyze issues related to the place and role of schooling in society. An emphasis should be given to both the uniqueness and the communality in the socialization of teachers, to the ways in which race, social class and gender mediate the socialization process. Thus different patterns should be developed for particular groups who teach in particular schools. Also more research is required in order to help the future technology teachers acquire a better concept of their role. Teacher socialization he argues, should be viewed as an interactive process: How teachers are shaped, in turn influence the structures into which they are socialized.

This point of interaction between teacher education and society, is taken by the next author, Klaus-Henning Hansen from Kiel University in Germany. He too questions the Technology Curriculum for all teachers, yet from a philosophical point of view, by elaborating upon the conception of technology, and the contribution of philosophy and sociology to a technological curriculum.
Hansen's main argument is that technology curriculum for all teachers should be grounded on the idea of 'Bildung' (Klafki, 1993), which extends the narrow concept of literacy and education by including character formation or intellectual and moral autonomy as an integral part of education.
Autonomy and self-determination are a challenge to the technological society, whose members have internalized its economical constraints. Technological Bildung takes up this challenge, by integrating a critical reflective dimension. Thus the core of such a curriculum should be a discourse on the cultural meaning of Technology.
Such a curriculum is expected to improve communication between technology,

science, and humanity teachers, to develop a broader awareness of problems and responsibility towards them, and to improve technology education in general. More meaningful learning should be achieved once social context is integrated with technical applications (Layton, 1991), with human interests and motives, criticism, norms and the values we ascribe to it (Olson, 1993).
The subject matter proposed in such a curriculum is contextual knowledge of technology, relevant to the expert and the layperson.
Hansen visualizes a change in the role of the technology teacher, from making things (action) to reflecting and thinking about the reason of ones' own action. Reflective learning could start with discussing focal questions such as: How can we control Technology? where are the limits? etc. (Mackay, 1992). More like a philosopher, the teacher would learn to pose 'why questions'.
The role of a teacher who asks for values in technology is not restricted to mental activity. His role is to construct and reconstruct relationships between real technical objects, and the interests and ideas behind them.
Finally the paper refers to the teachers role in curriculum development. He warns against the implementation of a teacher-proof curriculum, imposed from the outside administration, and argues that teachers as persons should create and adapt their own ideas in the curriculum (Schubert, 1986). A technology education curriculum, based on the teachers' own ideas, promises more reflective thinking on technology.
The centrality of the teacher, who is broadly and deeply educated, technologically literate, willing and able to play a new and demanding team role in an interdisciplinary, educational adventure with learners, is highlighted also in a paper by Douglas Crawford from Queens university, Kingston Canada.
A further elaboration of the issue will be found in the next section.
To sum up this section, STS teacher education could benefit from research on STS teaching and from our deeper understanding of our target population, namely the preservice and inservice students. The interaction between teacher education and society could be achieved by integrating a critical reflective dimension into the science and technological curriculum.

Curriculum development and its relation to teachers' professional development

The last group of studies includes a workshop and two papers, all of which present actual attempts, projects, or courses, that deal with the issue of teacher education or teacher preparation for their new role. The three cases portray different degrees of teachers' involvement in their own curriculum development.

A joint university and school workshop by Shaw, Nauman and Shaw, from South Alabama and Louisiana USA, focus on the aspect of gender bias, which they claim to be 'a fact of life' in public education of their country. Their emphasis is on the part of the teachers in discriminating between boys and girls (not only in subjects such as maths and science) and thereby reinforcing existing cultural attitudes and stereotypes. Their suggestion is to develop a plan of work, an

ongoing instruction on this issue, as part of teachers professional training.
The faculties in the two teacher training institutions represented by the authors, have successfully implemented a number of techniques, such as workshops and sensitivity sessions on gender bias, Videotapes and role-playing (Sadker & Fasker, 1993).
Their joint symposium is part of their ongoing effort to raise the consciousness of both pre and inservice teachers, so that they in turn, will encourage their students to counteract these cultural gender factors.
With respect to the degree of teachers involvement in curriculum development, judging from the collaborative team, one teacher was actually involved in the construction of the workshop.
The next two papers focus on actual inservice courses for STS teachers.

Myriam Krasilchik, from the university of Sao Paulu, Brazil, regards the curriculum as a powerful instrument of change, a vehicle of intellectual, social, political and economical progress. Referring to the science curriculum as an example, she reminds us of the great resources that have been invested in order to change and adjust the curriculum to the society and to the students' needs (Fenshaw, 1992). The issue of 'science for all' she argues, should be approached likewise, and dealt within a framework of fundamental educational policy. Decisions have to be made concerning its goals or knowledge basis. For example, whether STS knowledge should cater primarily to the personal development of the individual, or rather to his or her social development by forming citizens capable to contribute to the community.
A 'science curriculum renewal project' was initiated by a group of researchers from the school of education, consisting three phases:

1) Initial elaboration of teaching activities
2) Presentation of these activities in inservice teacher courses
3) A follow-up on the effects of these activities in the participating teachers' classrooms.

Qualitative data was collected by interviews, field notebooks and classroom observations. Six of the teachers who agreed to being observed, were video-taped. Triangulation of the data provided valid results.
The findings indicate that there was no change in the participating teachers' ideas about science and technology. They associated the concept of Science to 'acquisition and improvement of knowledge' and Technology to 'use of science to improve man's life'.
Participants benefitted from the INSET, mainly due to the opportunity to exchange ideas with colleagues and experts; to provoke reflection on current controversial themes and to be able to teach closer to the reality of the students. The follow-up stage in the participants' classrooms was problematic. Teachers were resistant to classroom observations and would not commit themselves to include the new teaching activities in the observed lessons.
It seemed that the INSET did not have enough impact to provoke curricular changes, or a change in their role conception. Although constructivist approach was an issue discussed in the course, the teachers greatest difficulty was to

accept students as partners in the construction of knowledge.
This same point is emphasized in a paper by Frits Gravenberch, Pien Barendregt and Paul van der Zande from the Netherlands. Relating to the SLO project, they too focus on the support given to teachers who implement 'Environmental Education for all', as part of their regular curriculum. One of their conclusions were that practising the constructivist approach caused more problems to the teachers than was expected.
Krasilchik's conclusions of her study are that "Short courses of the type described, serve at the most to reinforce already dominated competencies, but fail to bring about any truly profound changes, or even to overthrow resistance to change". Moreover, the issues discussed in the INSET were imposed by the organizers rather than stem from the teachers genuine interest or their prior experience. As such they failed to create an 'educational complicity' essential to authentic attempts to innovate.
The last paper, written by the author of this review, Keiny & Gorodetsky, Ben-Gurion University, Israel, addresses the problem of how to bring about a radical change in the STS teachers' role conception?
Since its introduction, STS has become accepted as an innovation in science education. Yet the meaning and implication of 'science for all' still remain vague, with most variant interpretations. 'Science for all', 'Integrated science' or 'Everyday science' all which are synonymous to STS, emphasize the aspect of relevancy, as compared to traditional science teaching, a more meaningful subject that would attract more students. Such an interpretation fails to meet the social aspect of STS, namely the *interaction between both Science and technology with society*. It does not address the basic problem: What is the role of society in STS?
One answer to this problem is provided by the manifested STS curriculum goals, namely to develop a conscious citizen, responsible for the welfare of the community, whether the specific one or the world as a whole. Another way of looking at the role of society is contextual, namely as our everyday reality, and as such as medium for learning, as medium for problem solving (Layton, 1993).
Constructing a rationale for STS, was the primary aim of The Israeli STS project, which was initiated by a 'leading group' of teachers and educational researchers. The second aim was to get the teachers to develop curricular units, which they themselves would then teach. The planned structure was a two tiered one, consisting of a central university INSET for teachers from 6 different high schools, with a second tier in the schools, where interdisciplinary teams of teachers will indulge in SBCD activity.
The paper focuses on the first phase of the project, namely the inservice university course for teachers of science and technology. Theoretically it is based on a model for teachers' conceptual change (Gorodetsky, Hoz & Keiny, 1993) which assumes that to teach STS teachers have to undergo a paradigmatic change, from their positivistic to constructivist orientation, which entails a change in their assumptions about learning and teaching, in other words, a change of their role conception.

The model suggests that teachers' conceptual change occurs in two interacting loci, a practical and a theoretical-social one. The latter is a reflective group where teachers exchange ideas, deliberate and reflect on them and thereby restructure their knowledge (Zeichner, 1993). The former is the teacher's locus of practice. In the project the context of the leading group acted as the theoretical locus, while the INSET group represented the locus of action, where ideas generated in the leading group were implemented. All session were tape recorded and transcribed, forming the data basis for the study. The aim of the study was to follow-up the process of mutual learning and understanding as an interplay between action and conception.

The findings indicate the teachers great difficulty in changing their pedagogical knowledge. The difficulty in substituting their conception of their role as transferrers of knowledge, (knowledge conceived as an external 'objective' entity) to conceive their role in terms of enhancing autonomous learners, who construct their own knowledge. It seems that the most painful part for them is to give up their main support, their dependence on the authority of knowledge, and instead take responsibility for their own knowledge construction (Keiny, 1993).

Changing their content knowledge was not easy either. It was enhanced by their exposure to interdisciplinary teams of researchers, who tackled authentic existential problems, such as How to grow crops on brackish water?, in other words How to survive in the desert?

Eventually STS was understood by the teachers not as another subject matter, another body of knowledge, but rather as a new learning orientation, based on two guidelines:

* Locating a real existential open-ended problem (which is by definition socially embedded)
* Turning the problem into a research study, or learning through an open ended problem solving process.

In the second phase of the project, teams of teachers in each of the participating schools, are expected to engage in STS curriculum development and experimental implementation. Having practised as learners, they are expected to be able to apply this orientation in their classrooms, guiding their students in active process of learning.

To sum up this section based on reports on actual courses of teacher education or preparation to teach STS, it seems that their success is very much dependent on the degree of teachers' involvement in their own curriculum development. INSET courses that stem from the teachers genuine interest and experience, have a better chance to prepare them for innovative roles. Moreover, it was indicated that teachers change of role conception, from positivistic to constructivist oriented, is not easy, most painful and requires time.

Discussion

The title of the Symposium: Science and Technology Education in a Demanding Society, points to the relationship between a society-in-change and between corresponding changes required in the educational system.
A rapidly changing society is not only a symptom of countries that undergo a significant political-social change, such as in Africa or East Europe. We are all subject to a dynamically changing reality, in terms of science technology, economics, as well as in cultural and humanistic values.
This is no more news, yet it seems that with all respect to recent and current reforms in science education, we are in many respects still lagging behind, and teaching in the old traditional ways. Most of our schools are not much different than a hundred years ago. Classrooms consisting of rows of individual students facing the teacher, and passively write down his words. As a representative of his or her culture or discipline, the teacher functions as a funnel through which knowledge is poured, to be retrieved later through a n elaborate system of testing.
Teaching Science for social responsibility, which is the present 'battle cry' of science education, though accepted ideologically, is in many respects still regarded by the classical educational pillars of our society, as an illegitimate baby who has to fight for recognition, and to prove itself before being accepted.
It is here that I discern the catch. Instead of judging STS according to its own manifested goals,its assessment is carried out in the wrong field, along traditional science education criteria. For example, students' achievements within the National curriculum examinations, their scores in the different scientific disciplines, is the major factor by which the accountability of the STS curriculum is judged.
This is the main obstacle the STS teachers confront, often finding themselves torn between two conflicting demands: Even those who feel the urge to innovate, to emphasize the aspect of relevancy, to deal with issues that stem from their own interest, and most of all to teach closer to the reality of the students, fear they would fail their pupils' required expectations in terms of the particular disciplinary requirements.
Notwithstanding the new winds in the air, the institutions for teacher education in most countries, maintain their old 'production line'. By training teachers to act as technicians, implementing the handed down curricular materials which were centrally planned by experts, they actually perpetuate the situation.
Picking up Alan Pilay's argument that there is no room for a 'top down' system of teacher preparation, a bottom-up, action research model is recommended, where teachers take responsibility for their own curriculum development.
This seems to be the general massage of most papers that constitute this section, that advocate different degrees of teachers' involvement. The highest could be a combination of the KwaNgwanase project and the Durban-Westville university model. Namely, a collaborative framework consisting of practising teachers university researchers, teacher educators, and student-teachers as well. Such an infrastructure will create an optimal medium for STS curriculum development,and

experimentally implemented. Curriculum development on the site, gives the best answers to the particular demands of the school or the classroom, both in terms of content and pedagogy. More important still, such a collaborative framework becomes a medium for a joint discourse between all participants, a laboratory for posing questions and testing new hypotheses, for elaboration over new goals and key concepts, for experimentation with new materials, reflection and self-evaluation of action.
Collaborative models in different variations, preferably in the school site, seem to me the ideal setting for the development of teachers who are responsible for their own system of knowledge construction, and as such are capable to take the role of developing active and more independent learners.

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STS-education: content and teaching methods, within strategies & empirical evidence

STS-education: perceptions, contents, teaching methods and evaluation of outcomes; A critical review/report

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Summary

Based on nine papers/presentations and one mini-symposium within the "STS education: contents and teaching methods" strand (sub theme: "Strategies and Empirical Evidence) at the recent 7th International symposium of IOSTE, the following issues of concern to STS proponents/educators have been identified: Students understanding of the nature of science, students' and teachers' perceptions of and attitudes towards STS, transfer of control of the learning process from teachers to students, the outcomes of STS teaching, the effects on students of implemented STS curricular units and STS-oriented teaching strategies, and the algorithmic/LOCS (lower-order cognitive skills) teaching-HOCS (higher-order cognitive skills) learning shift in science and STS education.

The main STS-related findings of and the conclusions derived-by the respective authors-from these empirical research-based presentations are: (a) there is a strikingly significant relation between the class teacher and students conceptualization of the nature of science; (b) students are lacking a basic understanding of the role of science and scientists in society, with no changes in their respective attitudes in spite of changes in the corresponding teachers' attitudes and learning materials; (c) teachers show positive responses to science topics which are related to society; (d) nontraditional multidisciplinary teaching affects students to become more self-regulating and more inclined to a constructivistic mental model of learning; (e) students are willing to learn scientific concepts, preferentially through the relevant contexts of sports and everyday-life rather than those of laboratory and natural phenomena; (f) computers can be particularly useful in helping students learn to treat realistic open-ended problems within science learning; (g) the application of an STS approach in teaching science results in the development of students' positive perception of STS teaching; (h) students enjoy units whereas their "STS teachers", although being appreciative of the instructional materials, are confronted with difficulties in translating some of the STS teaching strategies into applied practice in their classes; (i) students success on science examinations is in the order of algorithmic > LOCS > conceptual > HOCS and success on algorithmic does not imply success on conceptual / HOCS or even on LOCS questions; and (j) students can benefit from learning science through STS without jeopardizing their achievement in traditional science content.

Introduction

In view of the overly high expectations of people in a world of conflicting and competing values and finite, unevenly distributed resources, modern life has turned into a continuous process of problem-solving (PS) and decision-making (DM) or decision-selection from either available or as yet uncreated options (Zoller, 1991). However, although science and technology may be useful in establishing what we can do, neither of them (solely or jointly) can tell us what we should do. The latter requires the application of value judgments by socially responsible, rational citizens as an integral part of their critical thinking capacity. An emerging consensus has been thus materialized as to the urgent need for education reform in general and science education reform in particular (AAAS, 1994; NSTA, 1993; U.S. Dept. of Education, 1991; Yager, 1993; Solomon & Aikenhead, 1994).

A major purpose of science technology and environmental education is the development of students reasoning and ability to think critically in the context of both the specific content and processes of science and the process/interrelationships concerning societal, economical, scientific, technological and environmental issues within complex systems. The fostering of this kind of high-order cognitive skills (HOCS) is expected to enhance logical and reflective thinking which focuses on what to believe and what to do in terms of problem solving-decision making and responsible action to be followed accordingly (Zoller, 1993). Currently the "battle cry" of science education is teaching science for social responsibility (Cross & Price, 1992).

The crucial issue is the 'translation' of these super ordinate goals into science teaching strategies, examinations and evaluation of students' performance which are consistent with the above, given the present constraints of our primary/secondary school and college/university systems. Clearly, any progress towards the achievement of such goals require a shift in science teaching from the traditional science education to an STS-orientation in teaching science, which in turn requires an accord major conceptual change on the part of science teachers and students and the development-implementation of new STS (or STES; E stands for Environment) curricular units within which appropriate new teaching strategies -in consonance with these desired learning outcomes- will be applied.

The above is, in essence, what the strand "STS Education: Content and Teaching Methods" at the 7th IOSTE Symposium was all about while its sub theme -"Strategies and empirical evidence"- served as a guiding construct for the type of works submitted and presented within its framework.

STS education: content and teaching methods

The nine presentations and one symposium included in this report/review may be divided into three sub-groups under the umbrella title (above) of the symposium STS Education:

1. Student's Understanding of the Nature of Science and Students' and Teachers' Attitudes towards STS.
2. STS-related Teaching Strategies and their Effect on the Learning Process.
3. The Assessment of Students' HOCS learning , perception of and Response to STS Teaching, and the Effects of STS Science on Students.

Brief authors' summaries of the ten presentations here reported/reviewed follow.

1.1 Large-scale exploration of pupils' understanding of the nature of science

Joan Solomon, Linda Scott & Jon Duveen, Oxford University Department of Educational Studies, Oxford, United Kingdom.

The methodology of this research tried to span the small scale and the large, the qualitative and the quantitative, present knowledge and proximal development. It took account of the results of previous small scale questionnaire studies, interviews of groups of students and action research in the classroom concerning students' understanding of the nature of science.

Few questions were asked which referred to knowledge acquired from two different domains:

a. Out-of school images of science and scientist;
b. Ideas drawn from their own school experiences of science in the classroom and the laboratory.

The questions were to probe the connection between theory and experiment in terms which, we (the authors) had found, students of age 15 years, could understand them.

The results showed a strikingly significant relation between the class teacher and the responses to most questions. The exceptions were in out-of-school knowledge and confirmed our hypothesis about the two origins of students knowledge about the nature of science.

The students answers revealed the presence of two interesting groups of students: the 'Explainers' and the 'Imaginers'. The first of these seemed to be reflective, and as having a more explanatory perception of science. However, this was limited to their own laboratory experiences and did not extend to other cultures, or to the use of imaginative mental models. The second group -the 'imaginers'- were far fewer in the large sample of 15 year old, but comparatively more numerous in a small sub-group of older students at age 17. From their comparative success in questions about school experiments it would seem that

they are more receptive than others to teaching and also retain this knowledge better.

It was somewhat disappointing to find so little increase in the number of 'imaginers' from age 12 to age 15, and that only few teachers seem to be encouraging students learning to use theoretical models for prediction and appreciate uncertainty of evidence.

1.2 A longitude survey of pupils' attitudes toward STS - implications on learning materials

Itzhak Milgrom & Nava Ben-Zvi, The Science Teaching Center, The Hebrew University of Jerusalem, Israel.

During the years 1985-1992 a longitudinal, comparative survey project was undertaken in Israel, in order to establish the attitudes of grade-ten pupils, toward the role of science in society.

During this period, science curricula for primary and middle schools shifted from programmes that focused on scientific knowledge and means of scientific investigation to programmes that concentrated on equipping the pupils with a nucleus of scientific core concepts, laws, and generalizations , which are required by every citizen of the modern world, and which can also serve as a basis for advanced study of the sciences. The pupil learns to recognize the importance of scientific knowledge as it relates to technological developments, which have changed our social environment and living conditions.

The survey findings indicated that in the mid-80's, pupils lacked a basic understanding of the role of science in society, as well as the importance of those engaged in science within their own society. In spite of the change of attitude among the teachers and in the learning materials that were prepared in the second half of the 1980's, no significant change was found in the attitudes and positions held by pupils in these areas.

The conclusions from these findings relate to the need for more direct engagement of both students and teachers in those aspects in which there is a connection between science and technology. Relevant societal problems must be highlighted -- both those that are easily solvable, and those that necessitate a search for new solutions. Adopting the study methodologies preferred by the pupils has proven useful in media-rich environment. Use of educational technology is advantageous, aiding in the illustration of STS subjects.

1.3 What Hong Kong teachers think about STS in primary science

Yuk Hang Fung, Open Learning Institute of Hong Kong, Kowloon, Hong Kong.

As early as the eighties, the idea of STS (Science-Technology-Society) education was recommended by many science educators in various places. In Hong Kong, a curriculum analysis of the primary science curriculum using the science framework employed in the Third International Mathematics and Science Study indicated that the curriculum contains almost nothing in this perspective of science teaching. The objective of this study was to find out if primary school teachers accept the inclusion of STS objectives and topics within the primary science curriculum and what classroom activities they consider to be the most suitable for teaching primary science. The results indicated that teachers, in general, response positively to science topics which are related to society or the child's daily living. Teachers also consider that science curriculum should introduce to children the relation of science to technology and society. However, with respect to classroom learning activities, teachers are not keen of using role-playing, debates or simulation games.

2.1 The preparation of biology students for environmental or health education careers Process-oriented instruction to promote meaning and application directed learning styles.

Arend Jan Waarlo, Utrecht University, Centre for Science and Mathematics Education (CSMEU), Utrecht, the Netherlands.

Advanced biology students attending the environmental and health education course at Utrecht University will be confronted with an educational approach to which they are not used.
The Inventory of Learning Styles (ILS) was used to reflect on the corresponding teaching and learning process and to evaluate the effects of the newly implemented environmental and health education course. This course has turned out to be process-oriented, characterized by a gradual transfer of control of the learning process from instructors to the learners.
The ILS has proved to be a valid and reliable instrument to monitor the most relevant aspects of the intended learning process: self-regulation, concrete processing, and construction and use of knowledge.

2.2 Students' preferences on different contexts in learning basic concepts of mechanics

Jinwoong Song & Jung-Suk Choi, Department of Physics Education, Taegu University, Kyungsan-Kun, Kyungpuk-Do, South Korea.

The main purpose of this study was to investigate the extent of which Korean high school students are willing to learn certain basic concepts of mechanics

when they are presented in different contexts. Each concept was presented in six different contexts (i.e. laboratory, everyday-life, sports, military weapons, living things and natural phenomena) through which concrete examples of the context relevant to each particular concept were illustrated. Data from the survey on students' responses were analyzed for the preferred contexts by students and for meaningful differences in these preferences according to gender, achievements, student streams and school types. The results of the analysis were compared with the relative frequencies of different contexts used in Korean secondary school textbooks. Based on the results of the study, the way of presenting contexts of the scientific concepts in teaching materials are criticized and some suggestions for improvement are given, especially in relation to STS approaches in teaching science.

2.3 Where computers can help: a numeric programming environment

Denis Donnely, Siena Collega, Loudonville, U.S.A.

To prepare those students interested in scientific work for today's demanding job market, general problem solving skills are necessary. The computer can be particularly useful in helping students learn to treat more realistic open-ended problems. The ability to explore and the insight gained are two of the major advantages of this approach. The computer can be an effective tool in helping the student to develop strengths needed for modern scientific work.

3.1 A pilot study on teaching science by a STS approach in selected middle schools in India

Anil Banerjee, Regional College of Education, Mysore, India

A pilot study was conducted on development of a STS approach of teaching science in middle schools involving 180 students of classes 6 to 8 and three teachers of a school. Students perceptions about STS classes and nature of science were assessed by using two perception instruments. The results indicate that the students developed positive perception about STS classes and science.

3.2 The science across Europe project

Mariana P. Pereira, Departemento de Educacao, Fac. Ciencias, Lisboa, Portugal

The 'Science across Europe' project (ASE, 1991/1994) is an international project developed within the STS (Science- Technology- Society) perspective. Its curricular units are produced since 1990 by a team of European science teachers, under the coordination of the ASE, the Association for Science Education, in the UK.

The project consists of units that are tested and evaluated before being published. These units, each one in ten European languages, can be used together with the existing curriculum materials in every country. Students are expected to collect data that enables them to answer a few questions on science and technology and its implications on society. Then they exchange their results with students from other countries, filling in an exchange form. In order to do that, a data base of schools joining the project was established by the coordinating institution, and a network was also established.

This project is being used in Portugal and in European schools where the Portuguese language is used, since 1991. In 1993 an evaluation of its use in Portugal was carried out. A questionnaire was prepared and mailed to all teachers registered with the project. The response was 75%, but some of the teachers who replied did not answer some questions included in the questionnaire. The answers given on the experience with the units focused on the following: how were the units used; what were the teaching methods selected and resources used; and STS and the European dimension.
Suggestions for further use of the project are also presented.

The data collected revealed that the students enjoyed the STS units, whereas the teachers, although being appreciative of the instructional materials, did confronted with difficulties in applying some of the STS teaching strategies in their classes.

3.3 Teaching, learning and assessment of higher-order cognitive skills (HOCS) within S/T/E/S education in demanding society

Uri Zoller, Haifa University, Oranim, Israel

The driving force for our studies was an interest in moving science instruction from an algorithm-oriented factual recall approach dominated by LOCS (lower-order cognitive skills) to a decision-making, problem-solving and critical thinking approach dominated by HOCS.

The performance of freshman science, engineering and in-service teacher students as well as that of high school students in Israel, United States and Greece on algorithmic, LOCS, conceptual, and HOCS-type chemistry exam questions was investigated. University students' responses to specially designed algorithmic, LOCS, conceptual and HOCS exam questions were scored, and analyzed for correlations and for differences between the means within and across countries by the questions' categories.

Similarly, a 'post-factum' score data analysis of nationally administered general and competitive chemistry exams for secondary school graduates and LOCS/ HOCS take-home exam items preference of college students was conducted.

The main findings were:

a. Students in all countries studied performed consistently on each of the categories in the order of algorithmic > LOCS > conceptual > HOCS questions;
b. Success on algorithmic does not imply success on conceptual/HOCS or even on LOCS questions, that is: there is no correlation between students 'HOCS-and LOCS performance'.
c. Examinations, particularly those containing both HOCS and LOCS questions, can be effectively used to identify 'HOCS' - and 'LOCS-students',
d. Given a free choice, 'LOCS questions' are preferred to 'HOCS questions' by students, apparently due to their governing 'student-proof' attitude towards examinations;
e. Students taught in small classes outperformed by far those in large lecture sessions in all categories.

In consonance with the STS approach, the implied paradigm shift from an algorithmic/ LOCS to a conceptual/HOCS orientation, should be moved from a research-based theoretical domain to actual implementation of appropriate remedial and alternative HOCS-oriented teaching strategies, in order for a meaningful improvement of science teaching and learning to occur. Based on the above and previous related studies, the fostering of HOCS and conceptual learning are advocated. It can and should be done.

3.4 A mini-symposium: Science, Technology and Society Education

Glen A. Aikenhead and Joan Solomon - Organizers.

Several STS educators, who contributed to the book entitled "Science, Technology and Society Education" edited by this Symposium organizers, presented their views, perspectives, beliefs and criticism with respect to various aspects of STS education. A 'hot' discussion followed.

A key presentation within the Symposium was the following:

The effects of STS science on students
Glen S. Aikenhead, University of Saskatchewan, Saskatoon, Canada

This presentation examines the outcomes of STS instruction on students, with respect to a wide range of objectives, including learning traditional subject matter. It exclusively draws upon research that has been published in refereed journals over the past 30 years and also examines the possible harm that may result from replacing some traditional teaching with STS instruction. The conclusion to this review of research is straightforward: "Students can benefit from learning science through STS. Students benefit consistently and without jeopardizing their achievement in traditional science content".

An operational response to the all-pervasive question - "What is STS education all about?" may be: "STS education is what STS educators conceptualize it to be and, more important, what actually they are doing about it. That is, the STS-oriented activity, issues dealt with, teaching strategies and relevant research constitute the indicators of what STS educators or proponents priorize within the context of STS education and what they believe to be the main relevant issues of concern. In short, the STS-oriented research and teaching practice may serve as criteria of how those involved perceive and conceptualize STS education within the existing formal (but also informal) educational frameworks. A review/discussion of the strand's presentations in view of the above 'constructs' follows.

1.1 In their large scale research-based paper (1.1) the authors main concern were the long-term effects of contemporary traditional (not STS) science teaching on secondary school students' understanding of the nature of science. Believing that "... at heart of the epistemology of science lies the nature (social and procedural) of two entities, and the interaction between them - the observation or experiment and the theory or mental model", the authors focused on two domains: students' out-of school images of science and scientists and ideas drawn from students own school experience of science. By using both qualitative and quantitative methodologies in their research a strikingly significant relation was found between the class in which the students were taught and how they answered most of the question. The great impact of the teacher on students' understanding of science was evident. Also, the identification of the students as "explainers" (being reflective and having a more explanatory perception of science) and as "imaginers" (being more interested in what goes on the mind-imagining, expecting, explaining; and more receptive than others to school teaching) was made, based on their responses to the developed questionnaire(s). The main conclusions were that (a) by year 10 just over half of the students and over 80% at sixth form level, have unequivocally moved away from 'the cartoon image of science' towards a view of the nature of science and a deliberate search for explanation; and (b) only few teachers seem to be encouraging students to learn the use of theoretical models for prediction and explanation in the course of their scientific investigations and to appreciate the uncertainly in evidence.

What is the 'STS Connection' of this work?
If the science-technology-society interrelationships, their understanding, appreciation and taking a responsible action accordingly - constitute a major issue of concern to STS educators, then both students' perception and understanding of science and the demonstrated great impact of the science teacher on the student's views in these respects are very important relevant factors within the STS education context. Science teachers not only should use appropriate strategies... "to move students on from a worthy but limited empiricism towards the more existing realms of scientific speculation", but also can make this move

to happen. Although STS was not even once referred to in this paper, the authors' perspective of science with respect to its social and political (i.e. STS) dimension is apparent and their recommendation for special teaching strategies to be used in science teaching is in line with this STS perspective.

1.2 The attitudes of grade 10 high school students concerning the role of science in society (i.e. students attitudes towards STS) is the focus of the second paper (1.2) in the series. During the 1985-1992 survey period, a shift from programs for primary and middle schools, focusing on scientific knowledge to those concentrating on equipping the students with scientific core concepts and generalization in relation to technological developments and society needs ..."which are required by every citizen of the modern world", took place in Israel. A concomitant change in the students' attitudes and positions concerning the role of science in society was therefore anticipated. Clearly, if a change of students' attitudes in a predetermined direction is one of the objectives of a newly-implemented curriculum, then the need to examine the degree of success in attaining this objective is obvious. STS programs are no exception in this respect. Indeed, many studies examined via a "pre-post, control-treatment" design the change of students' attitudes towards science following the implementation of a new instructional program, all reported an improvement (e.g. Gogolim & Swartz, 1992).
By using four types of questionnaires, the fourth of which directly focuses on the students' 'STS attitudes', 1981 and 1615 students were surveyed in 1985 and 1992 respectively and the results concerning the students' choice of enhanced studies is science subjects, their ranking of social prestige and importance of those engaged in science, and their attitudes toward science in society were reported. To the authors' surprise, no significant difference was found in students' STS-related attitudes and positions in 1992 compared to those of 1985 in-spite of the "pro-STS" attitude change within the science teachers community as well as the "STS-oriented" learning materials that were prepared (and implemented) in the second half of the 1980's. The 'no difference' result could have been anticipated in view of the same result previously reported (Ebenezer & Zoller, 1993) for quite a similar scenario in B.C. Canada. The attainment of any educational objective requires a persistent, longitudinal, purposeful teaching effort, using teaching strategies and instructional materials which are in consonant with this goal. Therefore, the authors recommendation that in order to make a difference in students' STS attitudes, ..."a more direct engagement in those aspects in which there is a connection between science and technology" is very valid but not sufficient; the implementation of "STS-consonant" teaching/learning methodologies is mandatory if we, STS educators, want to win.

1.3 There is a consensus within the educational community that science teachers are the key for any meaningful educational change to occur. It is well-established that the teaching strategies employed by teachers are a result of their world views, belief systems, educational philosophy and attitudes. Therefore, in view of the recommendation by many for the implementation of STS education in schools

at all levels, a study was undertaken in Hong Kong (1.3), the objective of which was twofold: To find out if primary school teachers accept the idea of the inclusion of STS education within primary science curriculum and what specific classroom activities they consider to be most suitable for teaching primary science. Here, again, the issue of objectives-content-teaching strategies relationships for achieving a predetermined, agreed upon educational objectives (STS in this case) explicitly served as the constructs of the study undertaken. Fifty nine primary school teachers attending an in-service workshop constituted the survey population. A two-part questionnaire (15 items on attitudes towards, and methods of science, S-T-S relationships and science for higher study and career, and 15 items on the corresponding 4-category classroom topics in the personal, living world around, local and global context) was administered to this group. A overwhelming majority of the teachers (>95%) were in favour of the inclusion of an STS component ("Relation of science to technology and society") into the primary curriculum and, similarly, most of them (81-93%) were in favour of the inclusion of the corresponding relevant topics (e.g. human health & diseases, water treatment in Hong Kong, food problem in the world, energy resources and conservation). However, the use of debates/role-playing (extensively used in STS classes) as teaching/learning strategies in primary science teaching was not found to be considered as appropriate by the science teachers.

Since the issue-approach in STS education does require the use of these methods as well as an interdisciplinary approach, the author strongly suggests that ..."in-service programs should be arranged for teachers to modify such pre-conceptions of the teachers" ... if STS curriculum is to be implemented. Although everybody would agree with this, two closely-related issues remained untouched in the paper: (a) Do we have a research-based evidence that in-service programs can indeed bring about the expected conceptual modification? and (b) do we have any evidence for the occurring of the transformation from conceptual-attitudinal modification to actual behavioral modification "translated" into in-class STS action? The accumulating results of several related studies suggest that the response to these two questions is positive (Yager, 1993).

2.1, 2.2, 2.3 These 3 papers/presentations within the STS education strand are related to the STS theme via their focusing on important aspects of teaching strategies within the STS methods inventory. In the first one (2.1), the author advocates the use of process-oriented instruction aiming at teaching subject - specific knowledge and thinking strategies for constructing, modifying and using this knowledge in coherence, concomitantly with a gradual transfer of control of the learning process from the instructor to the learner. The formulated search questions were: (1) To what extent did the concept of process-oriented instruction apply to the course "Environmental and health education", and (2) How did this course effect the learning style of the participating students? The central course objectives were acquiring -- by the students -- "starting competence" and competence for professional growth via experiential learning

(exploration, conceptualization and application of concepts in new contexts) through which the students take more and more responsibility for their own learning. The experiential learning and the shift of the responsibility for learning from teachers to students constitute the two elements which connect perceptually this course and STS education.
The Inventory of Learning Styles (ILS) was used to reflect on the teaching and learning process in the course and to evaluate its effects particularly as far as self-regulation and concrete processing, construction and use of knowledge are concerned.
Although the results of this "pre-post" type mini-study (N = 15 students) did indicate a significant shift in terms of the latter categories -in accord with the course objectives- the author's own concluding comments should be well taken: "With the ILS we have measured students' perceptions, so we must be careful to conclude ... that students have already changed their learning habits"; and in view of ..."the absence of a control group we cannot exclude history effects".
Relevant (to students) contexts of science teaching (Newton, 1988) is the subject of the survey-type study reported in paper/presentation 2.2. The relevance of this topic to STS education and the issue-approach within it is apparent, especially as students' interests and motivation are concerned. Specifically in this study, the authors surveyed 716 grade 11 high school students in South Korea for their preferences on different contexts for learning basic concepts of mechanics, by using a specially developed questionnaire for this purpose. The order of students' context preferences was consistent: sports > military weapons > everyday life > living things > natural phenomena > laboratory.
While the highest priority given to the first two can easily be accounted for in terms of relevance to students in the particular local context (culturally bound), the lowest priority given to the last two (in connection with the teaching of concepts of mechanics), strongly suggests that traditional physics teaching (and, most probably, the teaching of the other science disciplines as the reviewer/reporter suspects) is conducted through the least interesting and relevant -to students- contexts. Interestingly, analysis of Korean middle and secondary school textbooks revealed the 'frequently used contexts' order to be: abstract > laboratory > everyday life > all the other contexts. The 'no match' between students' preferences of contexts and those in which science concepts are presented in traditional science textbook and, eventually, taught with all the implications involved.
Since relevant and meaningful (to the students) learning contexts in science teaching are of particular importance in STS education and equally so is the understanding (by students) of the S-T-S interrelationships, the linkage between this Physics teaching-oriented study and STS teaching is apparent. The authors' recommendations that (a) teachers must be aware of their students' context preference; (b) students must not be taught only within the contexts that they prefer; and (c) the selection of the topics to be taught should be made systematically rather than randomly, are well-taken. The last paper in the group (2.3) is not a research-based, but rather an experience-based advocating of the use of computers for helping students learn how to treat realistic open- ended

problems. The problem, as stated by the author, is that students in the U.S.A. are not educated to become creative nor to develop interpersonal skills which ..."permits one to see things in a fresh way" and ..."essential (since) many problems are worked out in groups" respectively.
A shift in emphasis from just arriving at the correct answer to evaluation of the result (i.e. what does the answer reveal and in what way did the problem instruct) is advocated with open-ended problems claimed to provide the grist for such exploration and interpretation.
It is the author's belief that in this context computers can be especially helpful and he discusses selected physics problems within college physics teaching as examples. Whereas every educator would agree that meaningful learning occurs whenever the student ..."enters in and grapples with the problem", the question whether or not numering programming with the aid of computers is the most effective means to achieve that and/or the meaningful dealing with STS problem solving, remains open and requires an appropriately designed relevant research for getting an answer.

3.1 The first paper in the last group of the STS Education strand reports about a pilot study on teaching science by an STS approach in selected middle schools in India. Specifically, the perceptions of 180 students concerning their three (6, 7 & 8) STS classes were assessed by using 2 specially-developed (by the author) questionnaires within a "pre-post " design. The STS approach in teaching was defined by the author as follows: ..."the teacher gives an overview of the topic/unit at the beginning of each session and then motivates the students to cooperative learning in group work and class discussion... specially... on environmental and societal issues related to science and technology... The STS focus is on development of decision making skills on S-T-S issues"...

The pre-post results indicated positive changes in the students' perceptions about both their STS classes" and science in terms of e.g. ..."we plan solutions to issues related to environment and society" and "science should deal with problems of the society and environment". However, it is not clear, from the given data and the following discussion to what extent, if at all, these changes actually contributed to the development of decision making skills on STS issues of the participating students or to their STS literacy. The author's conclusion that the students developed positive perceptions about STS classes and nature of science is encouraging assuming that positive STS perceptions are necessary predisposition for STS learning. The latter should be the goal; the former - the means.

3.2 The 'Science across Europe' is an European/international project developed within the STS perspective consisting of issue-oriented units that are tested and evaluated before being published and can be used together with existing curriculum materials in every country (ASE, 1991/1994). The exchange of collected STS-related data between students in different countries constitutes an important component of the project.

The results of an evaluation of the use of this project in Portugal (June-August 1993), in terms of "which units where used?", "which teaching methodologies we re-selected?" and "which comments did students and teachers make?" were reported in this paper/presentation.
Generally speaking, both students and teachers enjoyed the units, the various aspects related to the methodologies and teaching strategies involved, the exchange of information and the inclusion of STS-related issues. Teachers mentioned the difficulties in pursuing an interdisciplinary work within the teaching of the units and in conciliating the project with the traditional division among the disciplines. Although the increase of students' interest in the various aspects of communication was apparent as were the professional benefits to the teachers involved as a result of the networking, the most important question - whether or not the project attained its "STS objectives" and to what extent remained unanswered and, clearly, requires the initiation and execution of appropriate both formative and summative evaluation studies.

3.3 A major driving force in the current effort to reform science and technology education is the conviction of many that it is vital for our students to develop their higher-order cognitive skills (HOCS) capacity in order to effectively function in our modern, complex science and technology-based society. In accord with the above the conviction of the author of this paper (3.3) is that a major purpose of science, technology, environment, society (S/T/E/S) education is the development of:

- the students' reasoning and critical thinking ability in the context of the specific content and processes of science in general and S-T-E-S interfaces in particular, and
- their problem-solving decision-making capacity for so they can be effective citizens.
- this is guided by the ultimate educational ideal of the educated person: one who has the ability to be engaged in higher-order skill-based forms of inquiry (i.e. PS, DM, creative thinking) required both in the study of the discipline and in dealing with characteristically interdisciplinary everyday life situations;
- the knowledge base relevant to these situations;
- the ability to select and apply the relevant information and skills guided by reflective, responsible attitudes, and
- the motivation and self-confidence to act accordingly and to take responsibility.

In line with this guiding rationale, several of the authors' studies focus on the role of STS/HOCS-oriented examinations and the use of the assessment of students' 'HOCS/conceptual' vs their 'lower-order cognitive skills (LOCS)/algorithmic' performance for the fostering of students' HOCS capacity within STS-oriented teaching (Zoller 1993, Zoller et al, 1994). Clearly examinations as well as other assessment measures must be in consonance with, and in support of, the long-term objectives of STS education.
In the studies here presented, first year college science major students'

performance on specially constructed algorithmic, LOCS and conceptual questions within mid-term and final exams in three universities (two in Israel, one in the US; N=66, 48 and 576 respectively) was determined. In parallel, a post-factum analyses of the results of the general examination (GE) and the Panhellenic Chemistry Competition (PCC) held in Greece in 1991 for high school graduates (N=1352) as well as of the 'take home/ make your choice' mid (first) term exam in a general chemistry course for freshman biology majors (N=22) in an Israeli University were conducted.

These results strongly suggests that traditional methods and instructional strategies of teaching science are not compatible with the attainment by students of conceptual learning and higher-order cognitive skills. Neither are the current means of assessment; i.e., algorithmic/LOCS-oriented examinations, in consonance with the goal of acquisition of higher order cognitive skills by our students, regardless whether within traditional or STS-oriented science teaching.

The following were the main findings:

a. Students in all the three countries studies, performed consistently on each of the categories in order of: algorithmic > LOCS > conceptual > HOCS questions..
b. success on algorithmic does not imply success on conceptual/HOCS or even on LOCS questions, that is: there is no correlation between students 'HOCS- and LOCS performance';
c. examination, particularly those containing both HOCS and LOCS questions, can be effectively used to identify 'HOCS'- and 'LOCS-students';
d. given a free choice, 'LOCS questions' are preferred to 'HOCS questions' by students, apparently due to their governing 'student-proof' attitude towards examinations;
e. students taught in small classes outperformed by far by those in large lecture sessions in all categories.

In view of the findings the author argues that the implied paradigm shift from an algorithmic/LOCS to a conceptual/HOCS orientation, should be moved from a research-based theoretical domain to actual implementation of appropriate either remedial or alternative HOCS-oriented teaching strategies, in order for a meaningful improvement of science and technology teaching and learning to occur. Based on the above and previous related studies, the fostering of HOCS and conceptual learning are advocated. It can and should be done and this is in essence the task ahead for S/T/E/S education in our very demanding science and technology-based society. Many would agree with the "should be done!" ; yet, "how to do it" effectively, given the constraints of the existing educational system requires much further research work on both theoretical and practical levels and the translation of the results into educational action.

3.4 Several central issues in STS education that were raised and discussed by the presenters constituted the core of this Mini-symposium (3.4). A hot debate, in

which many of the audience participated ensued, centred around the following main points:

1. Does STS education improve students understanding of the interactions among science, technology and society?
2. Will students' achievements on traditional subject matter at the levels of science education following the STS-oriented science teaching, not be significantly compromised?
3. Can STS students make significant gains in thinking skills (e.g. critical thinking and decision-making) compared with students of traditional science classes?
4. Can STS students (compared to their non-STS students) significantly improve their attitudes towards self-reliance, civic responsibility, science and learning science?
5. Can students benefit from STS education within science teaching?

The speakers' response to questions 1 and 3-5 were unanimously "Yes" .. "contingent on ...." or ..."provided that"... which served the point of origin for the debate that followed. Question 2 drew most of fire on the part of the audience who argues that since (a) STS education is an alternative to the traditional ways of teaching science; (b) the objectives of STS education are totally different from those of traditional science education; and (c) STS education is, and should be, more demanding than traditional science education, comparing achievements of STS- and non STS-students by using the ordinary, commonly used assessment means (i.e. standardized tests and LOCS-type exams) and evaluation methodologies has no meaning. The bottom line is that ..."students can and do benefit substantially and consistently from STS education and teaching" - concluded the Symposium organizers.

Concluding Remarks

STS education provides a demonstrative advantage to students in the improvement of their STS literacy, their interest and understanding of the interactions among S-T-E & S, their capacity to responsibly take an active part in the decision making processes in democratic societies, their HOCS capabilities at critical thinking, logical reasoning, problem solving, and decision making as well as their evaluative thinking capability. Therefore, not only can STS education be successfully implemented, it should be applied as a leading construct of contemporary and future science education.

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STS cross curricular themes: environmental education; decision making - within strategies & empirical evidence

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Summary

The Seventh IOSTE Symposium encouraged participants to present empirical evidence concerning the techniques, curriculum, and theories about the cross-curricular nature of Science-Technology-Society education, in addition to curriculum, teaching methods, and teacher education. Eight presentations and two workshops accepted this challenge and presented a broad range of studies that focused on environmental education and decision making. Three broad themes were evident in the discussions that accompanied these presentations:

- Environmental education clearly includes skill building and problem solving activities, not only environmental knowledge.
- The methods for discovering what learners' think about the information and skills presented in STS and EE curricula, and how they develop the skills that are taught, are varied. The success of these methods provides us with insights into the learning and teaching process, and the effectiveness of the educational innovation.
- Scientific facts and information may not be heavily utilized in student decision making on science related social issues.

Introduction

Across our cultures, empirical evidence has become an accepted way of generating knowledge, particularly of concepts that may not be obvious at first glance. The field of education has been faulted for a reliance on rather intuitive knowledge about learning and teaching: learning is an individual process, often constrained by personality, subject familiarity, and social norms. Thus building good evidence of success in learning and teaching can be a challenge.

Eight presentations and two workshops accepted this challenge during the Seventh IOSTE Symposium, carving out for themselves one small piece of the education arena to explore, hypothesize, and offer new ideas for discussion. Their quest for further understanding form this review of "Strategies and Empirical Evidence in STS Environmental Education and STE Decision Making". Because the presentations spoke of a "state of the art" in research in these areas, this is an interesting and helpful lens through which to examine the current trends and research questions in environmental education and decision making.

There was a strong focus on qualitative research tools to understand more about how learners perceive and process information and decisions, and secondary emphasis on program implementation. As a result of these discussions, a third theme became obvious as an underlying assumption that was made by participants, that environmental education is much more similar to STS education than it is to traditional science education or nature study. Therefore, the following broad themes were echoed throughout this section, in presentations, discussions, contemplations, and conversations:

1. Environmental education is a process that helps learners identify and act upon environmental issues, making it akin but not identical to other STS curricula. Educators conduct EE in a full variety of avenues, from field trips to games, simulations and readings.

2. Learners' thought processes, while a key to understanding the effectiveness of the educational innovation, are assessed through various methods. These methods are constantly evolving, bringing us new insights and understandings into the learning and thinking processes.

3. Scientific facts and information may not be heavily utilized in student decision making on science-related social issues.

These three themes will be explained and developed in this review.

1. Environmental education's definition

Over the last three decades (Disinger, 1983) educators have discussed and debated their definitions of environmental education. A key question has ben the goal of environmental education: should EE increase learners' knowledge of the environment or increase their ability to solve environmental problems? Where the first entails a detailed study of ecology and cart systems, the latter requires additional knowledge about values; social, economic and political systems; skills in decision making and problem solving; and the opportunity to practice these skills. This diversity of subject areas clearly take EE out of the exclusive realm of the traditional science, even though science teachers are the ones most likely to first engage in environmental education. This diversity also raises practical implementation questions often echoed in STS discussions about the practicality of interdisciplinary projects, team teaching, etc.

Presenters within this track referred to environmental education as a process that encourages learners to identify and resolve environmental issues. In some cases, learners may collect field data about their ecosystem to become more acquainted with the effects of pollution (Fleszar, 1994). In other cases students need not travel outdoors; they read about environmental solutions or debate potential solutions as a group (Monroe, 1994; Kortland, 1994; Young and Monroe, 1994). Although concerns about interdisciplinary projects were not raised directly, these

presenters seemed to have access to teachers and schools where an individual was comfortable with the broad nature of EE, or where this definition of EE was accepted and encouraged.

The more typical debate about the purpose of environmental education was clearly not evident at this conference. Perhaps this is the influence of the STS movement that brings such uniformity to the environmental education presentations at this conference. Indeed, the recognition of science-related social issues and the responsibility of educators to empower learners to resolve them gives environmental educators license to include skill building and to approach value perspectives in their programs.

The growing acceptance of EE as an interdisciplinary, problem-solving process is indicated by a study of Dutch school department heads. Geography teachers are not significantly less proficient or knowledgeable about environmental aims that biology education, through biology teachers, is not the only successful entry point to the curriculum. Perhaps teachers of other disciplines are equally capable of engaging students in interdisciplinary studies of environmental problem solving. Indeed, it was hypothesized, a science teachers' training in a linear, scientific method of fact-finding, may hamper them from building skills important to helping students question, challenge, and resolve controversial issues where solutions are political compromises, not scientific results (Gaskell, 1994).

A workshop on environmental education resource design in southern Africa, however, catapulted this discussion of environmental education's definition from one merely confined to the content and process of the educational exchange to one where the process of designing materials and engaging in environmental education is reflective of the social reality (O'Donoghue, 1994). By noting the pattern of decisions and the changing issues that appear in various renditions of materials, O'Donoghue sees a reorientation of purposes that reflect the changing dynamics of southern Africa society. This is as important an element in environmental education as the content itself, as it empowers educators and more truly reflects their "environment".

2. Learners' thought processes

Our ability to measure the message or skill that students learn from an educational program helps determine whether or not that program accomplishes its goals. Educators typically use quantitative tests to ascertain knowledge and assume knowledge is an accurate measure or indicator of "understanding", "skill", and "learning". The presentations and discussion at this symposium, however, effectively broadened both how measures might be taken and what educators might use to explore effectiveness. The presentations began by assuming that students' memory of facts may not fully reflect what they learned or how well they can use this information.

Many presenters found that qualitative data, taken from recording discussions, interviewing students, written assignments, and interviewing teachers, played a critical role in increasing understanding about the learning process. As in any research project, care was taken in how the questions are asked, whether competing explanations can be ruled out, and the extent to which the researcher's conclusions are explained by the data.
Nevertheless, rich insights are available to those who pursue these research questions, and future questions beg to be answered. In discussions of these presentations, most of the questions focused on generalizing the specific results to other audiences, other topics and other situations. For example:

- Are younger visitors more likely to have conversations about animals at zoos than older visitors? Would older visitors be more likely to comment on the animal's ecology or endangered status? Is this conversation a potential measure of learning, ore merely short-term perception (Tunnicliffe, 1994)?

- Are students so capable of "playing the game of learning" that they only do to the minimal effort to complete worksheets that guide them through a decision-making process, or are their cursory notes indicative of how they approach decision-making? When judging student papers, what is the "ideal"? What constitutes "improved decision-making"? Would this be true for all types of decisions (Ratcliffe, 1994)?

- Are students more able to respond to challenges to their decisions that involve social information than those based on scientific information? Is their notion of science such that information is either accepted or forgotten, whereas non-scientific information may be questioned and challenged before acceptance? Are we not training science teachers to teach skills of debate, analysis and critical thinking (Gaskell, 1994)?

- To what extent is our in-depth knowledge of several cases of student decision-making ability (those of food containers, forestry, transporting hazardous materials) transferable to their abilities to approach, debate, reason, and reach decisions on other issues? How many other confounding factors might affect the way students approach decision making on these issues, e.g., prior knowledge, perceived locus of control, proximity of the issue, risk associated with the issue (Gaskell, 1994; Kortland, 1994; Ratcliffe, 1994)?

Presentations also suggested additional instructional techniques for affecting what learners perceive and remember. Written materials that increase text-based interest, for example, may alter how well learners read, remember, and feel about the topic (Monroe, 1994). Studies that only measure the information that students remember may be missing this underlying construct of interest that is likely to affect attitudes as well. Further studies that control for topic-based interest are needed.

A workshop presentation introduced participants to a quantitive method of assessing learning that was carefully designed to reflect students' misperceptions about energy (Viglietta, 1994). Such a tool may be best designed after a great deal of interaction and conversation directly with students, i.e., after a "qualitative" introduction to the situation, and after trials and discussions with teachers. By uncovering these misperceptions, the pre-test became a tool for discussion and review as the unit progressed, and positive results were obtained.

And finally, listening to learners' comments, questions and thoughts helped redirect one evaluation to include questions about source credibility and definitions of danger. Reactions to information that explains controversial, risky activities, for example, may indicate that students learned the information satisfactory, when in fact, they only repeated the answer and didn't really believe it. Interviews with students indicate their perceptions of "danger" and "radioactive" are quite limited; effective educational programs and their evaluation should take into account the prior beliefs and fears of the learners (Young and Monroe, 1994).

These studies and the questions they provoke suggest our tools for discovering how learners think, what they know, and how this changes with instruction are not very advanced. Many of the tools used in these studies have shortcomings or competing explanations for the results. Continued studies, with small attempts to triangulate toward a greater understanding with adaptations by other users, and with replication involving different audiences, were discussed as being helpful.

3. The use of scientific information in decision making.
Three presentations focused on exploring students' decision making skills (Gaskell, 1994; Kortland, 1994; Ratcliffe, 1994). Each presenter reported using in-depth student interviews to ascertain the decision making process.

One presentation specifically cited concerns about the lack of evidence that students use, rely upon, and defend decisions based on scientific information (Gaskell, 1994) and this became an interesting point of discussion in several presentations. Has the STS philosophy further eroded the little scientific literacy that schools provide by making societal aspects of issues more interesting that their scientific roots? Or, does STS provide more exposure to science-based issues that students received previously? Is the use of scientific information in decision making too much to expect of a non-scientist?

Certainly there is much to be learned about human decision making processes and the variations a classroom might impose: individual or group interaction, familiarity and prior knowledge, accessible or distant issues. The notion that humans make decisions according to an economic model of rationality, sorting out the costs, benefits, and probabilities, is open to different interpretations (Kaplan, 1991). Many researchers have articulated deficiencies with this model

(Simon, 1957; Kruglanski and Ajzen, 1983; Tversky and Kahneman, 1981). Simon (1970) suggests that humans "satisfice" rather than maximize in our decisions, chosing to take an opportunity that is "good enough" rather than wait in an uncomfortable state of indecision until the "best" is available. In addition, we rarely have complete and perfect information to base our decisions about environmental issues: we often lack key elements of information. Information that does exist may be debated by scientists, who may also disagree about the models used to make predictions where information does not exist. And information, however, perfect, is not always perceived similarly. Familiarity with aspects of some solutions bias us toward them, as well as comfort with the source of the information (Tversly and Kahneman, 1981). The risk communication literature also suggests citizens have a much different framework within which to evaluate risks than do the experts (Allman, 1985; Johnson, Sandman and Miller, 1992; Stern, 1991). Could we expect that scientific information from a textbook could be more powerful than social information from peers, or information about a new technology more trustworthy than common knowledge about a current technology, gleaned from experience?

Gaskell (1994) offered some insights into this dilemma by suggesting that students' decision making processes could be improved with practice in skills of challenging assumptions, questioning information, and discussing their own claims among themselves. Indeed, groups of students might arrive at different decisions than would the same individuals working alone. The interaction of the sociological and psychological aspects of decision making create a rich venue for future research.

Conclusion

The ten presentations in this section of the 7th IOSTE Symposium offered a rich assortment of information, evidence, and hypotheses about environmental education and decision making as cross-curricular themes in STS education. With regard to the three themes that were identified in this review, several broad summary statements can be made:

- Environmental education can be thought of as a "sister discipline" to STS education, sharing roots in societal issues and interdisciplinary efforts to teach information, skills, and values that will lead citizens toward solutions.

- The development of environmental education materials may be most useful when it follows a process that parallels and reflects the changes in society and empowers educators to adapt and create their own resources.

- It is not sufficient to measure educational success quantitative tests of knowledge gained. Rather, understanding, prior conceptions, mental processes, skills, and values are critical aspects of the educational experience that require additional measures and indicators to provide empirical evidence of success.

- Learning more about how students react to instructional materials may help us design materials that accomplish more of our goals.

- Measuring and evaluating decision-making skills is still a debatable and theoretical endeavour. Perhaps by removing assumptions of rationality in the decision-making process, new insights will be gained.

These are but a few of the insights that participants gained from the presentations and discussions at the Symposium. No doubt all the participants are looking forward to another equally stimulating series of presentations and discussions at the 8th IOSTE event.

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Science/technology education: contents and teaching methods - within strategies & empirical evidence

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Summary

Most of the empirical findings reported in this section were the result of quantitative research designs. Only a few used qualitative research methods. Despite the wide geographical separation of the researchers, a number of common research issues were present. First, STS curricula are seen as vehicles for changing pedagogy. Embedded in this issue is the concern over pedagogues, especially with the qualifications they require to teach from STS curricula. Second, all researchers commented on the power of the pre-existing syllabus. Implementing STS curricula required syllabus support. Third, this implementation process required strong family support. Parents seem to wish to see their children on the cutting edge of technology, especially computer technology.

Introduction

This paper presents a review of the seven papers presented in the portion of the program titled *Science/technology education: Strategies and empirical evidence*. The comments herein focus on research results. In other words, all comments are based on empirical evidence. The titles of the papers, as well as the authors' names, are presented in the bibliography. It was gratifying to see a truly international representation in this area. Researchers were in attendance from Africa, the Caribbean, the United States of America, Canada, Brazil, Britain, Venezuela, and Yemen.

This paper is comprised of three sections. The first section will deal with the research methodologies used in the various studies. The second section will deal with common research findings. The third section will report on the discussions surrounding each paper during the symposium.

A. Research Methods

A variety of research methodologies was employed. Several of the studies used quantitative methods to explore their research questions. Sonia Spencer (Spencer, 1994) used a pre-test/post-test design to evaluate the success of a new module on indigenous technology in junior secondary schools in Sierra Leone. Her data were then analyzed using a t-test. Abdallah Al-Farra (Al-Farra, 1994) also used this design in his study of three different techniques for teaching chemistry. He

also used a t-test for data analysis, but added a one-way ANOVA and the Newman-Keuls test to his analysis.

Gerald Krockover and James Lehman (Krockover & Lehman, 1994) used the pre-test/post-test design to assess the effectiveness of a program designed to train teachers to use Project INSITE. This was followed by the use of the same methods to assess the impact of the Project INSITE activities on students. Once again, the t-test was a major analytical tool.

These researchers were also interested in the change in students' attitudes brought about by their interventions. Likert type scales were the preferred data collection tools. The use of this technique for examining STS issues and student points of view has been examined and critiqued by Aikenhead (1988). It would serve the future research directions of the above mentioned scholars to give careful consideration to the ideas presented in Aikenhead's paper.

Jeannette Bascones (Bascones, 1994) employed several strategies to examine a meta-cognitive approach to problem solving in physics. A number of tests were designed to assess specific areas of content knowledge. Cluster analysis was used to analyze the results. As well, Bascones employed multivariate analysis when examining sub-sets of her data core.

More qualitative methods were used by Juca and Maskill, (Juca & Maskill, 1994) and Fleming and Pain (Fleming & Pain, 1994). In the former case, the researchers describe their methods as "semi-qualitative". In their study, this involved the use of a questionnaire, semi-structured interviews, and an observation schedule. All these techniques were brought to bear on the question of whether teachers explicitly consider their pupils' independent ideas in the classroom. Teachers were then labelled as "constructivist", "traditional", or "mixed". The paper needs to elaborate on how these categories were created.

Fleming and Pain used interviews with students, teachers, administrators, and parents to explore family-school interactions concerning the role technology should play in the education of children. The research questions arose when the two researchers were looking for linkages between theoretical models of technology and of family. The findings were based on an analysis of the transcriptions of all the interviews. Using constant comparative analysis, four main themes emerged from the data. In the second section of the paper, the findings in this study will form a contrast to the findings of Al-Farra.

B. Common Research Findings

It is a fascinating feature of international symposia discovering the common issues and concerns facing educators and researchers. A number of these are discussed below:

i) *Teacher issues:* All the researchers whose work involved changing a traditional curriculum to a curriculum with an increased STS focus argued that STS curricula are vehicles for changing pedagogy. Many of these comments were made during the discussions of the papers. Spencer, for example, saw her emphasis on indigenous technology requiring teachers to move from dictation science to discovery science, from chalk talk to discussion. Prime's work with the development of senior biotechnology courses echoes this. She drew on the work of Schwab (1973) and Goodson (1990) to argue, firstly, for Schwab's interactions between the four commonplaces and, secondly, for Goodson's perspective that knowledge is socially constructed. As Prime concludes, "Open-ended activities, opportunities for construction of meaning, flexible objectives, and evaluation tasks that allow students to express their unique understandings are informed by constructivist notions" (p. 702). This conclusion reflects the need for a new form of pedagogy.

Krockover and Lehman's work argues for a pedagogy which requires the use of electronic databases. They based their argument for this need in the summary report of the American Association for the Advancement of Science (AAAS), *Science for all Americans* (Rutherford, 1989). This report argues for increasing technology in the curriculum, although it must be noted that its opinion as to what computer concerns should be addressed are quite simple. As they conclude, "The role of the classroom teacher is a critical element in infusing technology into the curriculum and that role needs to be further explored" (p. 500). This is a very important comment. High technology pedagogy may be as stifling as direct instruction. The use of databases does not necessarily move pedagogy into other models of instruction such as concept attainment, synectics, cooperative learning, and so on. The old database, the teacher and text, were no guarantee of this either. More will be said about this in the third section of the paper.

Along with concerns about pedagogy were concerns about pedagogues. Specifically, teacher qualifications were an issue. Prime, for example, on discussing the introduction of biotechnology into sixth form in Trinidad, proffers that "teachers expressed some anxieties about their own level of subject matter competence" (p. 695). Smith offers suggestions such as team development of materials to reduce the uncertainty in teachers about the content of the lessons *and* the new instructional approaches required.

Al-Farra's paper highlighted his concerns over the shortage of teachers who could teach science, let alone S-T-S education. Once again, the chalk/talk format was seen as traditional teaching, with discussion of issues a healthy move away from this type of pedagogy.

Fleming and Pain were not concerned specifically with pedagogy. One of their findings, however, suggests as well a need to alter teacher education. As with the other researchers, this term discovered a need to engage students in reflection on and discussion of the impact of technology on their lives. this requires that teachers be prepared to be discussion leaders, not discussion dominators, that teachers learn how to deal with multiple possible answers to S-T-S issues, and that teachers be taught the social context of the need for hands-on activities.

Nowhere could this need be more obvious than in Project INSITE (Krockover & Lehman, 1994). What is the nature of a teacher education program which needs to prepare teachers for the world of INSITE? Are they to be technophiles? Can they be critics of educational technology? What do they need to know about learning through CD-ROM and interactive video? These questions were not the focus of this study; nevertheless, they suggest needs in teacher education.

ii) *The Tyranny of the Syllabus*: Researchers face a number of dilemmas when attempting to examine the effects of implementing an STS curriculum. Most of the papers which dealt with curriculum change commented vociferously on the power of the pre-approved curriculum syllabus. In response to questions following her presentation, Spencer described the teachers' concerns with "covering the curriculum" as soon as teaching methods appropriate to STS content were described. Prime was concerned with the time constraints created by the syllabi.

For Fleming and Pain, there is a different issue around curriculum documents. They acknowledged that their government approved curriculum supported an STS focus. This focus is reflected in the curricular syllabi. The question remains as to the "closeness of fit" between the mandated and translated curricula.

In all the cases where curricular change (and the evaluation of that change) was a part of a research agenda, the researchers commented on the power of the syllabus. A curricular document which approves content-based, didactic instruction flies in the face of the STS agenda.

iii) *Role of Parents and Families*: In all appropriate cases, researchers reported finding that parents/families played a central role in the implementation of new curricula. If there was inadequate parental support, the innovation would likely not succeed. The type of program supported varied.

Spencer, for example, found that the study of indigenous technology was perceived by families as a backward step. An educational innovation, then, was seen as requiring a move towards more sophisticated technology.

A central theme in the Fleming and Pain paper was an examination of what technologies parents felt should be taught about and/or used in schools. First of all, most of the parents interviewed had a very restricted meaning for the word "technology" -- but they felt they were surrounded by it! Its most common presence was felt to be computers. Most families argued that students required hands-on computer use in schools regardless of their future educational or employment plans. Thus, they would probably approve of Krockover's Project INSITE. On the other hand, they disapproved of distance education, fearing it meant the loss of classroom teachers. A combination of the two was a compromise. This response indicates that families expect to have qualified teachers in their schools.

In contrast, Al-Farra argued that distance education was necessary in a situation where there was a severe shortage of qualified teachers. Distance education became critical when students could only see a teacher one to two hours per month. It appears that the perceived usefulness of this technology varies with the availability of qualified teachers rather than, for example, widely separated pockets of people. If every pocket has one or more qualified teachers, distance education becomes a resource for the teacher to use. If teachers are in short supply, it <u>is</u> the teacher.

There is a sense in these papers that parents want to believe their children are on the cutting edge of technology, especially computer technology. They believe this will ensure their children's future academic and employment success.

In an earlier paper, Fleming (1989) had argued that STS curricula would focus on a critical examination of computer technologies. These present findings suggest there is support for this, but that most families wanted a balance between understanding the impact of technologies and practical, "hands-on" experience with them.

C. Issues Unique to Each Paper

The comments in this section are based on the discussion of each paper at the symposium. These comments are <u>not</u> summaries of the papers, as readers have direct access to the actual papers in the Proceedings.

Spencer's work with indigenous technology centred on the coalpot. The social situation for this study was interesting. Sierra Leone is a net importer of oil. Energy costs are high. Basically, there is an energy crisis, causing people to return to more traditional cooking methods using wood. Much clearcutting was done, causing serious erosion of landslides. In this context, Spencer created a teaching unit to assist students in discovering the most efficient coalpot design. This creates a strong link between school and home technology.

In one of her research sites, the students formed an environmental club. They

wrote to the mayor and the conservation society, informing them they had found a very efficient coalpot design. The students created a model of the pot and explained it to the conservation society. This group, in turn, approached a manufacturer who made one working model. This model performed wonderfully. Such a scenario as this must be the dreamed-about outcome for STS teachers!

Prime's work on a biotechnology component for Trinidad's students stirred some interesting discussion. Trinidad has a solid biotechnology industry. This group suggested examining only the local biotechnologies. Students had a major concern over the ethical implications of bio-technology. As a result, the economic and political issues of the technologies had to be dealt with. This paper presents another example of the roles played by various stakeholders in creating STS curriculum materials.

Another role model for such partnerships is found in project INSITE. This project asks students to learn to access and use large, varied databases. Much of the discussion was concerned with two questions: "Why did the researchers feel that students needed access to more information" and "How could students assess the reliability of their information"?

In response to the former, the researchers replied that the classroom materials developed for this project required students to use a variety of data sources and often required them to work cooperatively with students in other geographical areas to compare data. This too was done electronically.

The latter question was of some concern. To avoid the "garbage in-garbage out" problem, teachers and students need to be taught how to critique information. It did not appear that this was a major concern for this project.

Such projects often entail vast infusions of capital. Krockover argued personally, and in the article, that there are sources of available capital in a wide range of social institutions.

As readers know, Fleming and Pain's paper dealt with the data they collected in a rural research sight. The researchers were asked about urban students. This portion of the study had been completed just prior to the Symposium. Thus, they were able to report that based on an early analysis, they could detect no differences in the responses. It appears that modern family structures does not allow for the luxury of gendered use of technologies. Boys reported using microwave ovens to prepare meals for siblings: girls reported doing oil changes on vehicles.

A number of people were curious as to students' beliefs concerning the control of technology. Sadly, most students felt they had little if no control over technology. The exception seemed to be the on-off switch on a television set.

A number of questions were raised over Al-Farra's study. Several were methodological, concerning how one compares a teacher to a TV lecture to a computer simulation. Readers who are interested in this debate may wish to read the article by Kozma (1994) or perhaps the entire issue of that journal. Questions were raised about selecting teachers for the study and the nature of the support materials for them. Most persons felt they needed more details on the production of the television and computer materials.

It was interesting to note that all the "TV" students passed the post-test. This stimulated lively discussion about tests in general being biased towards a model of instruction or a technology. this was a key issue, for in this study students had access to television but not computers. It was generally agreed that more work needed to be done before the distance education model could be adopted for the entire country.

Bascone's paper on problem solving involved the use of Gowin's Vee. Bascones drew on the work of Novak and Gowin (1984), who argued that concept mapping and Gowin's Vee were effective methods for enhancing science learning. These techniques were also used by Biggs (1988) to study metacognition, a key component of Bascones's study. Much discussion arose over what Gowin's Vee was and how it was used. Concept mapping was also discussed. People were concerned with how one marked a concept map. For example, must it model the concept map of an expert problem solver in the area? There was also discussion on the relationship between the ability to create a concept map and conceptual understanding. This issue went unresolved.

Discussion

It would appear that one "world trend" is the tendency to use quantitative research designs to examine technology in STS programs. It is time to expand the research repertoire. Researchers should consider methodologies which require long term engagement with students, teachers and other stakeholders. In several countries, case studies have been used. Such studies done by individual researchers usually involve one or two sites. They require that the researcher be a competent observer and interviewer. However, the collected data usually allow for insightful descriptions of the day to day life of an STS curriculum in action.

There are international concerns with teaching methods and teacher training. These are inextricably linked. It is no longer enough for the teacher to employ only didactic instructional techniques. STS curricula require a breadth of methods, including class discussion, small group work, cooperative learning and the like. Teacher training institutes must ensure their teachers are competent in these areas. These methods are further legitimated if they are also found in course syllabi. STS educators and researchers have a responsibility to work towards curricular syllabi that require this breadth of methods. To the content

qualifications of teachers must be added pedagogical qualifications.

This concern over teacher training led to an unresolved dilemma. Specifically, if there were a shortage of qualified teachers, should instructional technologies take their place? It appeared that in those countries where school systems had access to capital for teacher in-service, these technologies were electronic assistants to the teacher. In those countries where capital was less available, they would become the teacher. This is one important area for future study.

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*NOTE: All references marked with an asterisk (*) are the papers presented at the 7th IOSTE Symposium and discussed in this chapter.

Science\Technology-education: education and industry

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Summary

Presentations and discussions at the Seventh International Symposium on World Trends in Science and Technology Education confirm the trend towards increased importance of education-industry links in science and technology education. Four particular issues are discussed in this review:

* the relationship between science and technology education and the aspirations of nations to compete in the global economy;

* the involvement of industry and education as co-educators;

* the improvement of learning outcomes for students through education-industry partnerships; and

* the factors which mitigate for and against education and industry working together.

Introduction

The involvement of industry in science and technology education has become increasingly popular. Examples of recent reports across a range of curriculum areas include environmental education (Dickinson, 1992), mathematics (Farrell, 1992), energy (Frantz, 1992), applied science (Grinnell and Sherman, 1992), agriculture (Diamond, 1993), chemistry (Russell, 1992; Bouma, 1994), health (Filipczak, 1993), careers (PACE, 1993), and science and mathematics (Kubota, 1993; Gottfried, 1993).

The growing importance of education-industry links has been observed in a number of countries (National Industry Education Forum, 1992) and attributed (Lepani, 1994; Sweet, 1994) to desires to:

* find a national competitive advantage in the global economy;

* improve the learning outcomes for students; and

* improve the learning cultures of enterprises in business and government.

These conclusions are confirmed by presentations and discussions at the Seventh International Symposium on World Trends in Science and Technology Education. At the Symposium two sessions were allocated to the theme 'Science and Technology Education and Industry'. Five papers were presented in these sessions: Anamuah-Mensa and Towse, 1994; Erossa, 1994; Gonzalez-Apaloaza, 1994; Mulroney, 1994; Munshi, 1994. A number of other Symposium papers also referred to education-industry links.

Science and technology education and economic agenda

One important issue is the relationship of science and technology education to economics - and in particular the relationship between science and technology education and international competitiveness as nations move to develop and apply intellect intensive capabilities to industrial value adding.

For example (Erossa, 1994; Gonzalez-Apaloaza, 1994), Mexico is undergoing dramatic economic change as it adjusts to compete in the global economy, having joined the North American Free Trade Agreement in 1993. Technology is seen as critical in establishing this competitiveness. In turn science and technology education is seen to have an important role in providing a technological edge. It is argued that to attain its goal of economic competitiveness, Mexico will require a highly trained labour force and that this will be enhanced by closer links between education and industry.

As a result it is now policy to link curricula to the productive sector. Gonzalez-Apaloaza (1994) describes an evaluation by one senior technical high school to test how closely its vocational program aligns with the views of industry.

Erossa (1994) describes another response in Mexico to the situation where 'the current technological needs of the country and the industry are challenging the traditional education options'. A Masters degree in Technology Management and Entrepreneurship has been developed to produce a new specialist who will provide leadership in the activities of technology planning, acquisitions, absorption, transfer and assessment. There is an increasing instrumental purpose to contribute to the solution of the industrial and social needs of Mexico. 'Thus, the curriculum design must be conceptualized as an activity to provide the linkage between academia and economic activities during the educational process'.

The argument is not too different in Australia where one reason that has motivated industry to take a more active interest in education is the desire to recruit highly skilled employees as a critical factor in being internationally competitive (Mulroney, 1994). The Chief Executive Officer of Australia's largest company has advocated changes in education to develop a workforce which is

'technologically competent and intellectually confident about its place in the global economy' (Prescott, 1992).

Other authors at the Symposium who make the link between education and economic agenda include:

Battacharyya (1994): 'India has to undertake appropriate science and technology education and research and development programmes to achieve her goal of economic growth and development.'

Novakova (1994): from the Czech Republic: 'New, scientifically founded approaches to the concept of educational systems must reflect new social-political conditions, the transformation of our countries to a market economy and a more consistent application of scientific and technological progress to the whole national economy of our countries, and in every sphere of life of our democratic society.'

Panwar (1994): 'In Alberta (Canada), business and community leaders, parents and people from all walks of life are telling government that a world-class education system is needed to compete in the world of the 21st century.'

Riquarts (1994): '...there will be an increase in pressure in Europe on qualification as a result of technological change and worldwide competition.'

Tiagha (1994): 'Consensus is growing among Africans and their development partners that a triad of essential capacities (human capacities, institutional and physical infrastructures), must be built to adequate levels so as to enable a self-sustaining growth and development. It is argued that the entire educational system needs to be reformed and strengthened so as to provide the appropriate technological skills needed for industrialisation.'

Williams (1994): 'Science and technology syllabuses have developed independent of one another in Australia. Technology seems to respond more directly to the economic environment than does science.'

The link of education and training to economic restructuring has been examined in detail by Lepani (1994) who argues that industry-education partnerships are an important element in developing innovations in learning to meet the challenge that the 'only basis of competitive advantage in the global economy is the ability to

learn faster than others and to implement action based on that learning'. This implies that national economic competitiveness relies in part on the achievement of world's best practice in learning and that industry needs to work with education to reach this goal.

I subscribe to that argument but it is important to apply it with care. For example, Corrigan and Fensham (1994) observe that it can be interpreted as a call for elite science education for the few who would become scientists and technologists beyond schooling. Saez and Riquarts (1994) remind us that a key challenge is to establish a learning strategy for sustainable development. And Dreyfus (1994) challenges us to consider that we fail as educators if we simply respond to the demands (or impositions) of society: that education must be leading changes to society.

A role for industry-education partnerships in increasing equity has been suggested by Silverman and Pritchard (1993) and an implementation has been described by Mulroney and Edwards (1993).

Another important point is that it is impossible to generalise across all countries in a world where the economic context varies dramatically. It is also hazardous to predict future changes in economies or to project how labour markets will develop. (Callan, 1994)

At several points in the Seventh Symposium the subject of the relationship between science and technology education and national economic objectives was discussed and debated but not necessarily resolved:

* several participants in discussion argued that the dependence of national economic competitiveness on a country's provision of science and technology education had been overstated by authors and that other more powerful factors had been ignored;

* it was certainly agreed that, in the context of demands on education to contribute to the economic development of nations, we need to work harder than ever to ensure -
  - a fair society in which quality science and technology education is available to all,
  - careful attention to environmental education and to the concepts of sustainable development, and
  - educational systems which serve the broadest of goals and which provide leadership to society.

There seems little doubt that this debate will continue, and will be a topic for consideration at the Eighth Symposium in Edmonton.

Industry and education in partnership

The second issue is the involvement of industry in science and technology education as co-educators. Anamuah-Mensah and Towse (1994) contend that industry personnel is an important group which has been excluded from developments in science and technology education, that it is a group which if included can increase the relevance of science education, and which can work with teachers to make a different but complementary contribution to curriculum development. The authors describe concerns in Ghana that science graduates are unable to use their science knowledge for their own personal growth or for the welfare of their community. In particular new graduates have little knowledge of the industrial applications of science.

The authors contend that teachers and industrialists have a different but complementary contribution to make to science education. In their project, teachers tended to emphasise pedagogical issues and played a role in the transformation of highly technical information into user-friendly materials. Industrialists tended to emphasise technical/technological issues and provided a specific base of knowledge in the application of science in industry.

One of the arguments (Mulroney, 1993) is that the challenges that face us as science and technology educators are so great that we need to harness every available resource. Industry represents significant human and physical resources which can add value to the education of our young people. If you accept this, the question then becomes not whether, but how education and industry can work together in partnership so that the interests and needs of all partners and most importantly our young people can be served.

In Australia (Mulroney, 1994) central initiatives have developed regional partnerships where industry and education can work together to apply their combined resources to achieve educational goals. Key themes which have emerged include:

* provision of professional development for teachers and industry trainers;
* development by teams of teachers and industry personnel of curriculum materials with an industry focus;
* provision of access to schools and students of specialised resources of industries and other local institutions including universities;
* programs which promote careers and opportunities in industry;
* programs which provide first-hand experience of industry for students and teachers;

* development of new post-compulsory education pathways in which students spend part of their time in school, part time learning in a workplace and part time in off-the-job training;

* increased focus on providing students with generic competencies and specific industry-specified competencies; and
* establishment of small local networks of schools and industry.

In this approach, the assumption is also that others than teachers and schools have a role to play as co-educators: it is assumed that:

> 'workers can teach, and through teaching expand their own skills' (Sweet, 1994).

The research of Lepani and Currie (1994) indicates that when employers are involved in real decisions about curriculum delivery, assessment of the learning, management of the program and student selection, their commitment and enthusiasm is increased and the quality of the course is increased. Sweet (1994) observes that these are often matters that schools have seen as their own particular prerogative (the educational equivalent of notions of management prerogative). Equally, this view needs to be replaced by more participative working relationships which work best 'not only when employers are genuine rather than symbolic partners in the educational process, but also when schools support and assist them in their role as co-educators.'

Improving learning outcomes

The third issue is the improvement of learning outcomes for students.

It is argued (Mulroney, 1994) that often industry is ahead of education in understanding that for futures the important competencies are not content-based but generic including:

* teamwork;
* communication skills;
* personal and interpersonal skills;
* ability to continue learning; and
* development of an ethics framework.

Munshi (1994) suggests that a science and technology curriculum which emphasises the components of the discipline of design and uses a problem-solving approach may be effective in achieving these objectives. He points out that technology often fails not because of technical aspects but because of failure to pay attention to the human aspects and link them to technical 'solutions': design is the conceptual link which integrates the technical and humanistic aspects, ensures a product or process meets the social, cultural and economic needs, and can adjust a product or process for different purposes for different groups. This suggests a problem-solving approach in science and technology education:

* to develop independent-learning skills and the ability to learn quickly;
* where content is learned when it is relevant to solving the problem;
* to develop communication skills and team-work skills;
* to develop skills to evaluate quality of information; and
* to develop methodologies, creativity, openness and insight.

De Jong (1994) has developed an approach using an industrial chemical process to engage students in debate regarding environmental issues and to assist them to form opinions of their own. To enable students to understand the arguments in the debate, assess their quality, and take and express their own point of view the concepts of integral chain management and sustainable development play a key role.

Hunt and Russell (1994) describe the objectives of the British General National Vocational Certificate to offer features sought by the Confederation of British Industry including:

* empowering individuals and raising their aspirations;
* developing communication, problem solving and personal skills;
* ensuring breadth of knowledge and understanding; and
* providing opportunities for progression.

Callan (1994) confirms the perspective that in the post-capitalist society there is an increased recognition of the importance of higher level skills with particular emphasis on abilities to:

* think abstractly and conceptually;
* synthesize information and apply knowledge systematically to complex and unique problems;
* communicate effectively; and
* work collaboratively.

It is argued (Sweet, 1994; Toomey, 1994) that many of the above learning goals can be achieved effectively through carefully designed workplace learning programs. Sweet (1994) advocates that:

* 'High quality vocational education will not occur without significant learning occurring in the workplace, without learning from experience and practice, without learning which is clearly related to particular work contexts.' and

* '...that structured and assessed learning in the workplace can form part of the accredited school curriculum with negotiated links to post-school employment and vocational education.'

These ideas are common in a number of countries including the USA, France, Sweden and Germany. The results of American research on how to construct

effective workplace learning programs have been summarised by the William T. Grant Foundation and are shown in Figure 1.

Figure 1: Lessons from Recent American Research on How to Construct Good Workplace Learning Programs

- Work is best learned by doing it.
- Not everything can be learned in the workplace. Classrooms are the best place for some types of learning to occur.
- Effective programs give students strong incentives to achieve at school.
- Some workplaces are better than others for learning.
- People need to learn about both the social and technical aspects of job performance.
- Students need to be both challenged and supported when they are learning in the workplace. Effective programs set high standards and help students to achieve them.
- Motivation should be built into the learning process.
- The tasks should be sequenced so that each builds on previous ones.
- The chance to transfer learning from one situation to another, to apply lessons learned in one setting in other settings, should be deliberately built in.
- Learners should be able to reflect on their learning to get the maximum benefit from it.
- The best incentive for employers to encourage them to participate is competent youth.
- Mechanisms should be in place to ensure that employers, students and schools keep their commitments.

Source: William T. Grant Foundation (1992)

Workplace learning is an increasingly popular idea in vocational education. Madjen (1994) notes : "The influence of the business community is needed to ensure that vocational education courses receive the same prestige and status as academic courses".

There are several recent research studies which seek to elaborate on the idea of workplace learning (Berryman and Bailey, 1992; Eakins, 1993; Elkins, 1994;

Sweet, 1994). Generally their findings suggest we should be optimistic about the potential for learning on the job. Eakins (1993) reports that in her study "students clearly indicated that the workplace 'context for learning' was a strong reinforcing factor in all aspects of the learning. The transactions between the students and their workplace environments figured prominently in their reflections. The importance of role models, encouragement, and a supportive learning environment were clearly factors which motivated students to learn.' Toomey (1994) attempts to draw together the findings of the research on workplace learning and maps the claims as shown in Figure 2.

Figure 2 A Map of Research Findings and Claims for Workplace Learning

Context

Situated Learning	The actual work that needs to be done is the driving force for the learning.
Community of Expert Practice	The learners work together with experts and become drawn into the community of expert practice.
Intrinsically Motivated Learning	The learning is self-fulfilling.
Co-operative Learning	By pooling their fragments of knowledge and using each other as scaffolding the learners gradually become more expert.
Competitive Learning	Constructive competition, say between teams, enables team members to use each other as scaffolding to improve team performance and appreciate the importance of competition.

Content

Domain Knowledge	The concepts, facts and procedures associated with a particular subject are learnt.
Tricks of the Trade	The problem solving strategies of the experts in the field are picked up with practice.
Task Management Strategies	Goal setting, strategic planning, goal progress monitoring, plan evaluation and plan revision are learnt.
Learning Strategies	Learning how to learn.

Methods of Learning

Modelling	Learners model expert practice.
Coaching	Learners are helped directly by the expert towards expert performance.
Scaffolding	The actual supports provided to help the learner carry out the practical task.
Articulation	Learning by thinking out aloud.
Reflection	Any technique that allows a student to compare their own problem solving with that of an expert.
Exploration	Any device that gets the student into their own mode of problem solving.

Source: Toomey (1994)

The author suggests that the map could be used by industry and education partners as a basis for constructing future vocational education and training programs which seek to improve technology and science competence. He warns, however, that this task should not be approached uncritically because learning on the job involves more than developing technological knowledge and skills. The challenge is to devise site-driven applications of workplace learning "which not only increase technology and science competence but also produce attitudes and abilities to address the social dilemmas that accompany the inevitable growth of our technologised society'.

Industry-Education partnerships: When do they work?

The fourth issue emerging from the Symposium relates to the factors which mitigate for and against education and industry working together.

The experience in Ghana (Anamuah-Mensah and Towse, 1994) suggests that while industrialists are initially sceptical about the need to be involved in science and technology education, that enthusiasm increases with involvement: 'Industrialists are reluctant to interfere in the process of schooling but they need to be empowered to participate...'

Smithers (1992) argues that the "future for business-education partnerships rests with being able to justify themselves in terms of explicit criteria". He describes a Value Assessment technique which evaluates whether a partnership brings real benefits to both the company and education.

One of the results of Australian research (Lepani and Currie, 1993) is that industry involvement in education is promoted by an understanding that in the process much personal development is provided to industry personnel - that in the process of teaching students in the workplace or in the process of jointly developing curriculum materials with teachers, industry personnel develop their own communication and supervision skills, their understanding of their own workplace, their self-esteem and motivation, and their training skills.

Other factors which encourage industry involvement in education include (Lepani and Currie, 1993; Lepani, 1994; Sweet, 1994):

* an increasing realisation in the business sector that success is assisted by a quality community environment and that this will be assisted by closer collaboration with education;
* desires by employers to ensure appropriate skill development among the future workforce through practical experience and to influence students' career choices ('Many employers and their workers feel the lack of this type of learning in their own school education, and are keen to provide a form of education they would have wished to receive at school.' - Sweet, 1994);
* a desire by employers to return something to the community; and
* an understanding by companies that such involvement can assist future recruitment.

My observation is that three new factors have emerged which are encouraging industry and education to work together. First, there is now a wider range of options for commitment by companies. In the past enterprises were asked to provide sponsorship or simple 'work experience'. Now enterprises can choose to be involved in such increasingly mainstream activities as:

* providing opportunities for students to engage in planned workplace learning experiences;
* programs to influence students educational and career choices;
* new models for entry-level training which involve partnership between schools, industry and training providers;
* enriching the school curriculum by providing access for hands-on visits of students to company sites;
* teacher release to industry programs;
* development of curriculum materials by education-industry teams; and
* co-operative professional development with teachers and industry trainers in the same programs.

Second, industry-links are encouraged by the provision of local/regional support (Mulroney, 1994). The establishment of regional networks has been a critical success factor in the work of Victorian Industry Education Partnerships. These networks have been able to identify the local needs and the local organisations with the resources to meet those needs. In each group it is possible to identify a

number of key individuals who have been instrumental in the genesis and success of the networks and who have been 'champions' for the concept of forming links or partnerships to achieve objectives (Mulroney, 1993). Other authors have also pointed to the value of organising alliances locally (Clark, 1984; IEC, 1988; Stevenson, 1993).

Third, it is increasingly understood that it is necessary to use a partnership approach for the benefit of all participants. Perhaps the greatest difficulties to be faced in the establishment of industry-education links are issues related to control and ownership. Who is telling who what to do? Are there hidden agenda? These concerns are probably greatest on the side of educators. Certainly they were the subject of discussion at several points during the Symposium. In my view the solution lies in the concept of partnership. When industry-education links are established they should be established as genuine partnerships. The projects should be chosen where the objectives are shared by the education and industry partners, where the inputs are provided by all partners, where all partners (including students) stand to gain by the outcomes. In the words of one industrialist: 'It is important that the development of these partnerships between schools and industry is one that is fostered with an understanding of mutual goals' (Bowman, 1993). And of another: "I hope that business and education will cease to regard themselves as two separate cultures, and that working together will become a natural activity and a normal part of doing business. If we can work together in partnership, we will jointly contribute to enhancing the quality of life for us all" (Swanson, 1992). Perhaps most importantly, industry-education projects will only succeed if there is genuine and mutual trust. This will not always be achievable but probably works best where it is based on human interaction: the development of personal relationships between participants.

Lepani (1994) presents a model for understanding the power of partnership, by applying the *Enterprise Web* described by Reich (1992). In this model schools are redesigned as enterprise webs where hierarchal systems and structures are replaced by networked learning systems and structures. These enterprise webs comprise complex networks and linkages to form nodes of 'value' in time and place. Each point on the web represents a unique combination of skills brought together in response to a particular situation.

> 'Both the education system at the meta level of systems development, and the school at the local level of service provision, are becoming increasingly borderless. They involve complex networks, relationships and strategic alliances, in order to provide services which are appropriate to different 'customer' needs, and to marshal the physical and intellectual resources to sustain quality and innovation in the design of these services.
>
> Because schools play such an important role in both skill formation and the cultural reproduction of society, their customers include not just the students themselves, but their parents and community on the one hand, and on the

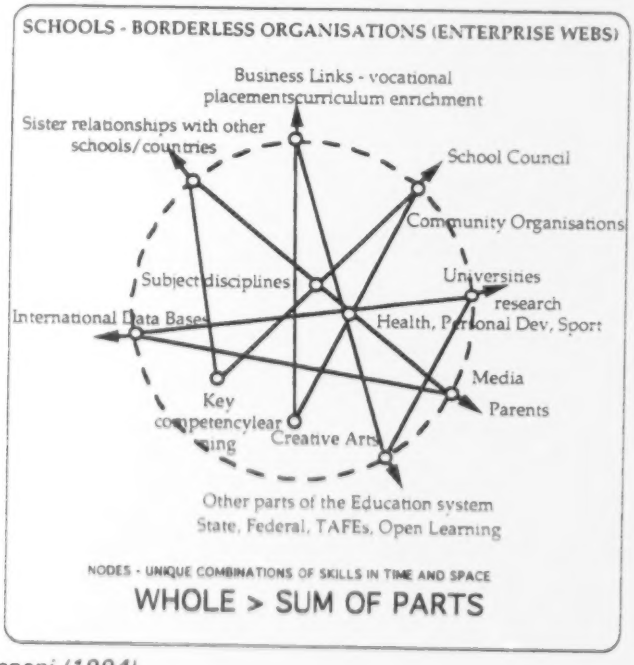
other hand, the employers who will depend on their having the appropriate skills, knowledge and attitudes to contribute to enterprise performance in an increasingly competitive economy.

At the level of the school, such enterprise webs are already in evidence as schools form relationships with local enterprises to provide vocational placements for new secondary courses in years 11 and 12, and to provide curriculum enrichment and professional development opportunities for teachers, develop links to international data bases and knowledge management systems, 'sister' relationships with schools in other regions or cultures, and build strong relationships with their local community.' (Lepani, 1994)

Figure 3, see next page, shows an attempt by one group of school teachers to represent their school as an enterprise web.

Partnerships with industry are a vital element in these enterprise webs where schools are working across boundaries to apply every available resource and access new learning opportunities to add value to education and training.

Figure 3 Schools as Enterprise Webs



Source: Lepani (1994)

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Conclusion

The trend towards growing importance of education-industry links seems likely to continue. Perhaps the most important reason is the conclusion drawn by nations that their competitive position in the global economy will be determined in part by their ability to develop high quality human resources. The demands of society in this regard will continue to impact particularly on science and technology education. Increasingly nations will expect business and industry to become involved in science and technology education and training to ensure that every available resource is applied to the achievement of world's best practice in learning. In this we will need to be careful that we continue to work for a fair society, for the provision of a quality science and technology education for all.

We are coming to an understanding that industry personnel have a role to play as co-educators in science and technology. Models are being established where industry and education work together in partnership to design, implement and assess science and technology programs. One effective method to facilitate this approach is to establish support infrastructure on a local/regional basis.

A number of countries have implemented workplace learning programs. This is an attempt to find a more effective approach than strictly school-based efforts to achieve a range of learning objectives. In particular, workplace learning is claimed to be effective in the achievement of goals considered critical for the future: teamwork, communication skills, personal and interpersonal skills, problem-solving, and ability to continue learning. There is a need for more research to improve our understanding of the critical factors in the effective application of workplace learning to science and technology education.

Research is beginning to provide information about the factors which are likely to enhance industry involvement in and commitment to education. All point to a need to develop a genuine partnership between industry and education, rather than an approach where one uses the other for its own ends. One relatively new understanding is that industry stands to gain by development of its own employees' communication and supervision skills, understanding of their own jobs, training skills, and motivation and self esteem. Sweet (1994) argues that this can represent the first step in the enterprise itself becoming a learning organisation.

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